# PATENT ABSTRACTS OF JAPAN

(11)Publication number : 06-281909
(43)Date of publication of application : 07.10.1994

(51)Int.Cl. G02F 1/13
G02F 1/1333
G02F 1/1335

(21)Application number : 05-092300
(22)Date of filing : 26.03.1993

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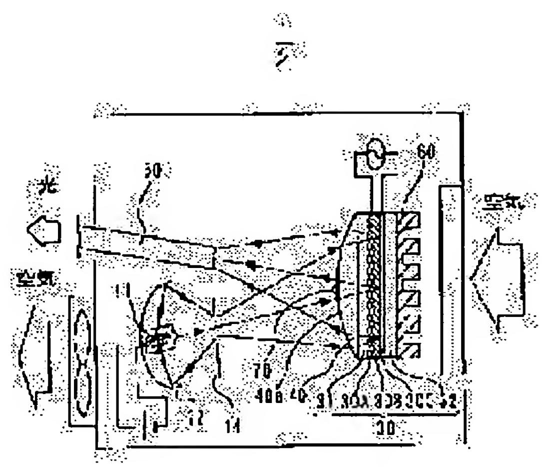
## (54) LIQUID CRYSTAL OPTICAL DEVICE AND ILLUMINATOR USING IT

(57)Abstract:
PURPOSE: To provide an optical modulator with high performance.
CONSTITUTION: This device is constituted so that a liquid crystal optical element 30 provided with an elliptic mirror 12, a light source 11, an aperture diaphragm 14, a front electrode 30A, a liquid crystal solidified substance composite body layer 30B where a beam passes through twice and a rear electrode 30C, a flat convex lens 40 and an optical fiber 50 are provided, and a boundary in an optical path is made a projecting and recessing surface, or is made to have an inclined angle α, or a light absorbing body 70 is provided on the surface 40a of the flat convex lens 40 and an unwanted normal reflection beam is reduced, and a modulated beam is emitted to the optical fiber 50.



LEGAL STATUS
[Date of request for examination]
[Date of sending the examiner's decision of rejection]
[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]
[Date of final disposal for application]
[Patent number]
[Date of registration]
[Number of appeal against examiner's decision of rejection]
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## CLAIMS

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[Claim(s)]
[Claim 1] The light source, a condensing means, and the liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix between the substrates of a pair with an electrode, respectively are pinched. Light is scattered about, in case liquid crystal is controlled by the electric field generated in inter-electrode and the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix. The liquid crystal optical element equipped with the liquid crystal solidification object complex layer which light penetrates when the refractive index of liquid crystal was mostly in agreement with the refractive index of a solidification object matrix, A light reflex means and an optical fiber are prepared, and it is prepared so that a light reflex means may bend an optical path in the middle of the optical path from the light source to an optical fiber. A liquid crystal optical element is arranged at the reflector side of a light reflex means, and the light by which outgoing radiation was carried out from the light source is made to pass a condensing means. Furthermore, incidence is carried out from the 1st field of a liquid crystal optical element, and it is made to pass a liquid crystal solidification object complex layer. Furthermore it results in a light reflex means, is reflected with a light reflex means, and is made to pass a liquid crystal solidification object complex layer. Outgoing radiation is carried out from said 1st field of a liquid crystal optical element, and it is made to pass a condensing means. In the liquid crystal optical equipment by which the quantity of light which is mostly condensed by the optical input edge of an optical fiber, and is transmitted to an optical fiber from the light source by transparency and dispersion of the light in a liquid crystal optical element is controlled A light reflex means is approached or stuck by the liquid crystal solidification object complex layer, and a condensing means consists of a plano-convex lens. [ whether this plano-convex lens is prepared in contact with said 1st field of a liquid crystal optical element, and irregularity is prepared in at least one interface among the interfaces which exist in an optical path until it results / from the light source / in an optical fiber, and ] Liquid crystal optical equipment characterized by making at least one interface incline only in only whenever [ predetermined tilt-angle / alpha ] to a light reflex means.
[Claim 2] Liquid crystal optical equipment characterized by forming irregularity in one [ at least ] electrode surface of a liquid crystal optical element in the liquid crystal optical equipment with which irregularity was prepared in the interface of claim 1.
[Claim 3] It is liquid crystal optical equipment characterized by considering as a bigger value than the prospective angle when expecting the effective radius of an optical fiber from the point on a reflector [ in / whenever / tilt-angle / on the liquid crystal optical equipment with which only whenever / tilt-angle / of claim 1 / alpha / was made to incline, and / in alpha / a light reflex means ].
[Claim 4] Liquid crystal optical equipment characterized by preparing a light absorption object or scatterer in the part on the convex of a plano-convex lens in the liquid crystal optical equipment of any 1 term of claims 1-3.
[Claim 5] Liquid crystal optical equipment characterized by forming a heat regulator in the substrate side with which the light reflex means of a liquid crystal optical element was

established further in the liquid crystal optical equipment of any 1 term of claims 1-4.
[Claim 6] Liquid crystal optical equipment characterized by coming to prepare an ellipse mirror further as a light guide means from the light source to a liquid crystal optical element in the liquid crystal optical equipment of any 1 term of claims 1-5.
[Claim 7] In the liquid crystal optical equipment of claim 6, the light source is arranged near the primary focus of an ellipse mirror. [ whether cone-like prism and an aperture diaphragm are put together and arranged as a condensing equalization means near the secondary focus of an ellipse mirror, and ] Or it is liquid crystal optical equipment which a cone-like reflector is arranged, and the outgoing radiation light from the light source is condensed near the secondary focus in an ellipse mirror, and is characterized by the flux of light further converged and equalized by said condensing equalization means carrying out incidence to a liquid crystal optical element.
[Claim 8] Liquid crystal optical equipment characterized by considering as the convex cone object-like prism whose vertical angle theta by the side of the optical outgoing radiation of cone-like prism is 90 degrees - 175 degrees, or the convex cone object-like prism whose vertical angle phi is 185 degrees - 270 degrees in the liquid crystal optical equipment of claim 7.
[Claim 9] Liquid crystal optical equipment characterized by considering as the convex reflector whose vertical angle beta of the reflector of a cone-like reflector is 150 degrees - 177 degrees, or the concave reflector whose vertical angle gamma is 183 degrees - 210 degrees in the liquid crystal optical equipment of claim 7.
[Claim 10] The lighting system equipped with the liquid crystal optical equipment of any 1 term of claims 1-9.

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[Translation done.]

## DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Industrial Application] This invention relates to the liquid crystal optical equipment using an optical fiber and the liquid crystal optical element of the transparency dispersion mold equipped with liquid crystal solidification object complex, and the lighting system using it.
[0002]
[Description of the Prior Art] A liquid crystal optical element is arranged between the light source and the optical fiber for optical transmissions from the former, and the liquid crystal optical equipment which controls the quantity of light transmitted to an optical fiber from the light source by the liquid crystal optical element is known. Furthermore, the lighting system and luminous-intensity-distribution equipment using the bundle fiber, the light source, and the liquid crystal optical element which bundled the optical fiber for optical energy transmissions or the optical fiber of single track are proposed.
[0003] Moreover, an optical fiber is used for the light guide means from the light source to a liquid crystal optical element, and the configuration which has arranged the liquid crystal optical element between optical fibers is proposed. The basic arrangement is shown in drawing 7 as a conventional example. The optical fiber 51 for incidence, the optical fiber 52 for outgoing radiation, a convex lens 41, and the liquid crystal optical element 30 in reflective mode separate spatially, and are arranged. Furthermore, the liquid crystal optical element 30 has a liquid crystal solidification object complex layer as electro-optics-stratum functionale in the interior, and shows the mode of operation of a transparency dispersion mold. And this configuration attains the modulation of light.
[0004] Moreover, although it is the arrangement configuration which resembled this conventional example, the optical variable attenuator which used the low loss thin line optical fiber for optical-communication information transmissions for the optical optical incidence [ of a liquid crystal optical element ] and outgoing radiation side is proposed. As mentioned above, since reduction of optical loss is attained by using the liquid crystal optical element equipped with the liquid crystal solidification object complex which has the mode of operation of a transparency dispersion mold, and can control light without a polarizing plate, even if it uses a high-reflective-liquid-crystal optical element and a lens, it is proposed that optical variable attenuator can be built.
[0005]
[Problem(s) to be Solved by the Invention] In this case, in order that light may pass a liquid crystal solidification object complex layer twice by considering as the configuration of a reflective mold, the scattering power of the liquid crystal solidification object complex itself improves by leaps and bounds compared with the configuration of the transparency mold which light passes once.
[0006] However, in order for a part of interface reflection produced in the interface of a liquid crystal optical element, the interface of the lens for condensing, etc. to always carry out incidence to the optical fiber by the side of optical outgoing radiation, when liquid crystal solidification object complex was in a dispersion condition, the outgoing radiation quantity of light from an optical fiber did not become low, and the extinction ratio of the outgoing radiation light

by the electrical-potential-difference impression to a liquid crystal solidification object complex layer and un-impressing was not able to say that it was high compared with the configuration of a transparency mold.

[0007] Therefore, the dynamic range of the quantity of light change accompanying electrical-potential-difference impression of a liquid crystal optical element hardly improved as compared with the component configuration of a transparency mold, and it was still a low characteristic value. Moreover, when the light source which emits a lot of light was used, it was remarkable, the repeatability of various kinds of electro-optics properties (the property of applied-voltage pair light transmittance, a dynamic response characteristic, extinction ratio, etc.) became low, and exact modulated light of the temperature rise of the liquid crystal optical element accompanying the radiant heat etc. was not completed.

[0008] Moreover, the outgoing radiation light from the light source was condensed in the ellipse mirror, and in the case of the lighting system which finally obtains outgoing radiation light from an optical fiber, the field where an illuminance is low was generated in the center section of the exposure side, and it had become a problem as a homogeneity lighting system. For example, since judgment precision would fall if it puts on the test equipment which performs a binarization image processing and judges the quality of mounting and the homogeneity within a field of exposure light is inferior after irradiating the outgoing radiation light from an optical fiber and inputting the image into the circuit board in which electronic parts were mounted with a CCD camera, it had become a problem.

[0009]

[Means for Solving the Problem] This invention between the substrates of a pair with an electrode with the light source and a condensing means, respectively The liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix is pinched. Light is scattered about, in case liquid crystal is controlled by the electric field generated in inter-electrode and the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix. The liquid crystal optical element equipped with the liquid crystal solidification object complex layer which light penetrates when the refractive index of liquid crystal was mostly in agreement with the refractive index of a solidification object matrix, A light reflex means and an optical fiber are prepared, and it is prepared so that a light reflex means may bend an optical path in the middle of the optical path from the light source to an optical fiber. A liquid crystal optical element is arranged at the reflector side of a light reflex means, and the light by which outgoing radiation was carried out from the light source is made to pass a condensing means. Furthermore, incidence is carried out from the 1st field of a liquid crystal optical element, and it is made to pass a liquid crystal solidification object complex layer. Furthermore it results in a light reflex means, is reflected with a light reflex means, and is made to pass a liquid crystal solidification object complex layer. Outgoing radiation is carried out from said 1st field of a liquid crystal optical element, and it is made to pass a condensing means. In the liquid crystal optical equipment by which the quantity of light which is mostly condensed by the optical input edge of an optical fiber, and is transmitted to an optical fiber from the light source by transparency and dispersion of the light in a liquid crystal optical element is controlled A light reflex means is approached or stuck by the liquid crystal solidification object complex layer, and a condensing means consists of a plano-convex lens. [ whether this plano-convex lens is prepared in contact with said 1st field of a liquid crystal optical element, and irregularity is prepared in at least one interface among the interfaces which exist in an optical path until it results / from the light source / in an optical fiber, and ] The liquid crystal optical equipment (1) characterized by making at least one interface incline only in only whenever [ predetermined tilt-angle / alpha ] to a light reflex means is offered.

[0010] Moreover, in the liquid crystal optical equipment (1) with which irregularity was prepared in this interface, the liquid crystal optical equipment (2) characterized by forming irregularity in one [ at least ] electrode surface of a liquid crystal optical element is offered. Moreover, in the liquid crystal optical equipment (1) with which only whenever [ this tilt angle / alpha ] was made to incline, alpha offers the liquid crystal optical equipment (3) characterized by consider as a

bigger value than the prospective angle when expect the effective radius of an optical fiber from the point on the reflector in a light reflex means whenever [ tilt angle ].
[0011] Moreover, in any one of the above liquid crystal optical equipment (1) – (3), the liquid crystal optical equipment (4) characterized by preparing a light absorption object or scatterer in the part on the convex of a plano-convex lens is offered.
[0012] Moreover, in any one of the above liquid crystal optical equipment (1) – (4), the liquid crystal optical equipment (5) characterized by forming a heat regulator in the substrate side with which the light reflex means of a liquid crystal optical element was established further is offered.
[0013] Moreover, in any one of the above liquid crystal optical equipment (1) – (5), the liquid crystal optical equipment (6) characterized by coming to prepare an ellipse mirror further as a light guide means from the light source to a liquid crystal optical element is offered.
[0014] Moreover, in above liquid crystal optical equipment (6), the light source is arranged near the primary focus of an ellipse mirror. [ whether cone-like prism and an aperture diaphragm are put together and arranged as a condensing equalization means near the secondary focus of an ellipse mirror, and ] Or a cone-like reflector is arranged, the outgoing radiation light from the light source is condensed near the secondary focus in an ellipse mirror, and the liquid crystal optical equipment (7) characterized by the flux of light converged and equalized by said condensing equalization means carrying out incidence to a liquid crystal optical element further is offered.
[0015] Moreover, in above liquid crystal optical equipment (7), the liquid crystal optical equipment (8) characterized by considering as the convex cone object-like prism whose vertical angle theta by the side of the optical outgoing radiation of cone-like prism is 90 degrees – 175 degrees, or the convex cone object-like prism whose vertical angle phi is 185 degrees – 270 degrees is offered.
[0016] Moreover, in above liquid crystal optical equipment (7), the liquid crystal optical equipment (9) characterized by considering as the convex reflector whose vertical angle beta of the reflector of a cone-like reflector is 150 degrees – 177 degrees, or the concave reflector whose vertical angle gamma is 183 degrees – 210 degrees is offered.
[0017] Furthermore, the lighting system equipped with any one of the above liquid crystal optical equipment (1) – (9) is offered.
[0018] In the liquid crystal optical equipment of this invention, it is detailed irregularity's specifically being formed in one [ at least ] transparent electrode surface of a liquid crystal optical element as an unnecessary normal reflected light reduction means, or making the liquid crystal solidification object complex layer of a liquid crystal optical element incline to a light reflex means, and preparing, and the unnecessary normal reflected light produced in the interface of a liquid crystal solidification object complex layer and transparent substrate glass with an electrode etc. is reduced.
[0019] Moreover, one-structure is adopted and a compact, the liquid crystal optical equipment which was optically [ firmly and ] excellent mechanically, and a lighting system are offered so that the unnecessary normal reflected light by the interface between a condensing means and a liquid crystal optical element may be controlled positively.
[0020] Moreover, in the liquid crystal optical equipment of this invention, an ellipse mirror is first adopted as a light guide means from the light source to a liquid crystal optical element, and a condensing equalization means is established further. The light source is arranged near the primary focus of an ellipse mirror, and an aperture diaphragm, cone-like prism, or a cone-like reflector is arranged in the location near the secondary focus. It is easy to attain the function that an aperture diaphragm is equivalent in addition to a perfect aperture stop here. Simply, the electrode holder of cone-like prism also functions as an aperture diaphragm. Furthermore, it is effective, if black painting is carried out or it is delustered. It is good to use a formal aperture stop preferably.
[0021] Incidence of the light which the outgoing radiation light from the light source was condensed in the ellipse mirror by the location near the secondary focus, and was equalized as about one flux of light with the condensing equalization means is carried out by this configuration to a liquid crystal optical element. In this case, it is possible by using cone-like prism and an

aperture diaphragm, or a cone-like reflector to equalize the luminous-intensity-distribution distribution of light by which outgoing radiation is carried out from an optical fiber as a condensing equalization means which is the component of a light guide means. And the optical fiber shutter for optical energy transmissions (lighting system) is offered, for example.
[0022]
[Function] According to this invention, the light guide also of the strong flux of light by which outgoing radiation was carried out from the light source, and the thick flux of light or the flux of light of single wavelength is carried out to a precision, and it is made to transmit to an optical fiber. In order that light may pass a liquid crystal solidification object complex layer twice at this time, the effectual scattering power of a transparency dispersion mold optical element improves. And by making an unnecessary normal reflected light component reduce positively, a noise component is made to reduce greatly and light with strong reinforcement is also correctly transmitted by low loss. Consequently, degradation of an extinction ratio and a dynamic range which were looked at by the conventional example is improved, and transfer control of light with strong reinforcement is attained.
[0023] Moreover, without having direct effect on the light on an optical path until it results [ from the incidence to the liquid crystal optical element of light ] in outgoing radiation, when a heat regulator is formed in the rear face of a liquid crystal optical element, it becomes possible to carry out temperature control of the liquid crystal optical element compulsorily, and the electro-optics property of a liquid crystal optical element is stabilized extremely. Furthermore, precise transfer control of light with strong reinforcement can be attained. Hereafter, an example explains this invention concretely.
[0024]
[Example]
(Example 1) The example 1 of this invention is shown in drawing 1 . As for the liquid crystal optical equipment of this invention, the ellipse mirror 12, the light source 11, and an aperture diaphragm 14 are used as light source optical system. In this example, the light source 11 is formed in the location almost near the 1st focus of the ellipse mirror 12, and the aperture diaphragm 14 is formed in the location almost near the 2nd focus of the ellipse mirror 12. The halogen lamp is used as the light source 11. Here, the filament part of a halogen lamp is installed in the location of the 1st focus, and the circular aperture diaphragm 14 is installed near the 2nd focus. Of course, the light-emitting part of a filament part has the volume which exists spatially, and is not the perfect point light source.
[0025] The optical fiber 50 which outputs light is arranged, and are the side front of the liquid crystal optical element 30 and the liquid crystal optical element 30 which has the reflective mold mode of operation which performs light modulation, and a plano-convex lens 40 is formed in contact with the close outgoing radiation side of light, and the 1st becoming field. In contact with the 2nd field, a heat regulator 60 is formed in the background of the liquid crystal optical element 30, and it consists of a drive circuit (illustration is omitted) which drives the liquid crystal optical element 30 further, an electrical circuit which carries out drive control of the heat regulator 60.
[0026] This heat regulator 60 is located in the background of a substrate 32, and pastes up the heat sink in which the thermo sensor and the electrical heater were built. Furthermore, the fan for air cooling was attached behind this heat regulator 60, and it could be made to carry out by the electrical heater and the fan for air cooling the temperature control, acting as the monitor of the temperature so that the liquid crystal optical element 30 may be maintained by laying temperature. Each of these components are dedicated to a case and cooled by air-conditioning by the fixed air flow.
[0027] What bundled the fiber of the numerical aperture (N.A.) 0.57 which uses multicomponent system glass as a core with a diameter of 50 micrometers, and was used as the bundle fiber with a diameter of 5mm was used for the optical fiber 50 by the side of optical outgoing radiation. It arranges in the location at which the main normal reflected lights arrive, and the circular aperture diaphragm 14 and the core of the end face of an optical fiber 50 (bundle fiber) are respectively installed in physical relationship [ **** ] mutually optically near the focal location of a plano-convex lens so that light may carry out incidence by eight incident angles to liquid

crystal solidification object complex layer 30B of the liquid crystal optical element 30 respectively.
[0028] The focal distance is 50mm and the plano-convex lens 40 was pasted up on the 1st field (side front) of the liquid crystal optical element 30 with optical adhesives (illustration is omitted). Moreover, the coat of the antireflection film was carried out to convex surface 40a of a plano-convex lens 40, further, the black coating was applied to the form of the shape of a spot with a diameter of about 5mm, the light absorption object 70 was formed in the core, and reflection of the part was lost.
[0029] A suitable value exists with regards to the effective diameter of the optical fiber 50 which uses the formation location and area of a black coating, and the convex configuration of a lens. It is desirable to form in the normal reflective location of lens convex surface 40a in which the reflected light in the convex of a lens carries out incidence to the optical fiber by the side of outgoing radiation. Although a black coating is applied to a part of convex surface 40a of a lens, the light absorption object 70 is formed and the unnecessary interface reflective component is reduced in this example instead, irregularity may be formed in the same field, scatterer may be prepared, and unnecessary normal reflection may be reduced.
[0030] The reflector of the ellipse mirror 12 was used as the cold mirror. The conjugate image corresponding to the effective diameter of the optical fiber 50 which is a bundle fiber makes the diameter of the aperture diaphragm 14 installed near the 2nd focus of the ellipse mirror 12 the configuration comparable as the conjugate image in the location by which image formation is carried out with reflexible flesh-side electrode 30C and the reflexible plano-convex lens 40 of the liquid crystal optical element 30.
[0031] By this example, since the conjugate image was formed at the rate of actual size, specifically, opening with a same as an aperture diaphragm 14 diameter [ as an outgoing radiation side bundle fiber ] of 5mm was installed. Moreover, the glass filter which has the spectral characteristic which absorbs or reflects ultraviolet rays and a heat ray was installed in this opening so that the ultraviolet rays and the heat ray which are contained during lamp luminescence might not carry out incidence to a liquid crystal optical element.
[0032] Only the light which the light by which outgoing radiation was carried out from the light source 11 was condensed in the ellipse mirror 12, and passed the aperture diaphragm 14 progresses to a plano-convex lens 40. Incidence is carried out from convex surface 40a of a plano-convex lens 40, and it is made to be refracted and progresses to the liquid crystal optical element 30. Furthermore, incidence is carried out to the liquid crystal optical element 30, and front electrode 30A in it and liquid crystal solidification object complex layer 30B are passed, and it reflects here in un-transparence flesh-side electrode 30C which is also an electrode and is also a light reflex means while remaining.
[0033] And liquid crystal solidification object complex layer 30B and front electrode 30A are passed again, a plano-convex lens 40 is passed further, and outgoing radiation is carried out from the convex surface 40a, and it is refracted and goes to the optical incidence edge of optical fiber 50 **. And it converges mostly in the location of this optical incidence edge, and incidence is carried out to an optical fiber 50. Next, it outlines about the configuration of the liquid crystal solidification object complex used by this invention.
[0034] In the liquid crystal optical element in this invention, the liquid crystal display component which pinched the liquid crystal solidification object complex with which distributed maintenance of the nematic liquid crystal was carried out into the solidification object matrix is used. It is desirable to use the liquid crystal solidification object complex it was made mostly in agreement [ complex ] with the Tsunemitsu refractive index (no) of the liquid crystal which distributed maintenance of the nematic liquid crystal which has a forward dielectric anisotropy especially is carried out into a solidification object matrix, and the refractive index of the solidification object matrix uses. And liquid crystal solidification object complex is pinched between substrates with the electrode of a pair.
[0035] no of a nematic liquid crystal When the refractive-index anisotropy which is a difference with an extraordinary index (ne) is set to **n, as for **n, it is desirable that it is 0.18 or more. Moreover, in order to obtain scattering power with a high liquid crystal solidification object

complex layer to the specific wavelength lambda (micrometer), it is desirable that the mean particle diameter R of liquid crystal (micrometer) has gathered according to the wavelength. In fact, it is desirable to fill the relation of ** n-R**lambda.
[0036] Therefore, when modulating the light of the wavelength band (lambda=0.4-0.7 (micrometer)) of the light using the bundle fiber for optical energy transmissions, in order for the scattering power in a liquid crystal solidification object complex layer to become homogeneity mostly in a full wave length region, it is desirable to be distributed over the range in which the mean particle diameter R of liquid crystal fills the relation of 0.4<**n-R<0.7.
[0037] When, using the light of the semiconductor laser diode of a non-light region, or the single wavelength of the near-infrared wavelength region (lambda=0.8-1.6 (micrometer)) of LED as a light on the other hand using the single track fiber for optical communication, or when using for optical measurement the light of the single wavelength of the helium-Ne laser which is the laser of a light oscillation, or semiconductor laser, the mean particle diameter R of liquid crystal has the desirable structure with little particle size distribution where ** n-R**lambda is filled.
[0038] As for the substrate with this electrode, that by which the electrode was prepared on substrates, such as glass, plastics, and a ceramic, is used. The configuration could be fixed and a substrate may be a flexible substrate like plastic film. Moreover, the substrate which has the spectral characteristic which absorbs or reflects ultraviolet absorption, infrared absorption, or an unnecessary wavelength component may be used.
[0039] A transparent ingredient is used for the substrate by the side of plane of incidence at least in this invention. Glass is suitable for forming few still flatter and optical distorted substrate sides.
[0040] Between the substrates of a pair with an electrode, liquid crystal solidification object complex is pinched, respectively. Electric field occur by impression of an electrical potential difference, this liquid crystal solidification object complex changes the orientation of a liquid crystal molecule according to that electric field, and the refractive index of the liquid crystal in liquid crystal solidification object complex changes. When the refractive index of the solidification object matrix is mostly in agreement with the refractive index of liquid crystal, light penetrates, and light is scattered about when not in agreement. Since the liquid crystal optical element using this liquid crystal solidification object complex does not use the polarizing plate, an optical modulator with little optical loss is obtained.
[0041] The liquid crystal solidification object complex which specifically consists of a solidification object matrix by which a large number formation of the hole fine as a liquid crystal display component was carried out, and a nematic liquid crystal with which the part of the hole was filled up is used. This liquid crystal solidification object complex is pinched between electrode substrates. The refractive index of the liquid crystal changes and the relation between the refractive index of a solidification object matrix and the refractive index of liquid crystal changes with the impression conditions of an electrical potential difference inter-electrode [ the ]. When these both refractive index is mostly in agreement, it will be in a transparency condition, and when refractive indexes differ, a liquid crystal optical element which will be in a dispersion condition can be used.
[0042] The liquid crystal solidification object complex which consists of a solidification object matrix by which a large number formation of this fine hole was carried out, and liquid crystal with which the part of that hole was filled up is the structure by which liquid crystal was confined in a liquid bubble like a microcapsule. However, each microcapsule does not need to be independent completely and the liquid bubble of each liquid crystal may be open for free passage through a slit like a porous body. Furthermore, the degree of a free passage may be high and in the condition which liquid crystal is opening for free passage in the shape of a stitch is sufficient.
[0043] The liquid crystal solidification object complex used for this invention is the following, and is made and manufactured. A nematic liquid crystal and the hardenability compound which constitutes a solidification object matrix are mixed, and it is made the shape of the shape of a solution, and a latex. Subsequently, what is necessary is for photo-curing, heat curing, hardening by solvent removal, reaction hardening, etc. to carry out this, to separate a solidification object matrix, and just to take the condition that the nematic liquid crystal distributed in the

solidification object matrix.
[0044] Since the hardenability compound to be used can be hardened within a sealing system by making it photo-curing or a heat-curing type, it is desirable. When a photo-curing type hardenability compound is used especially, it cannot be influenced by heat, can be made to harden for a short time, and is desirable.
[0045] After forming a cel using a sealant like the conventional usual nematic liquid crystal as a concrete process, pouring in non-hardened mixture [ compound / a nematic liquid crystal and / hardenability ] from an inlet and closing an inlet, it can heat whether an optical exposure is carried out and can also be made to harden.
[0046] Moreover, in the case of the liquid crystal optical element in this invention, not using a sealant, non-hardened mixture [ compound / a nematic liquid crystal and / hardenability ] can be supplied on the substrate which prepared the reflector as a counterelectrode, and the substrate which prepared another transparent electrode can also be stiffened by optical exposure etc. in piles after that.
[0047] Of course, after that, a sealant may be applied on the outskirts and the seal of the circumference may be carried out. According to this process, in order for what is necessary to be just to only supply a roll coat, a spin coat, printing, spreading according non-hardened mixture [ compound / a nematic liquid crystal and / hardenability ] to a dispenser, etc., an impregnation process is simple and productivity is very good.
[0048] Moreover, into non-hardened mixture [ compounds / these / nematic liquid crystals and hardenability compounds ], spacers, such as a ceramic particle for substrate gap control, a plastics particle, and a glass fiber, a pigment, coloring matter, a viscosity controlling agent, and the other additives that do not have a bad influence on the engine performance of this invention may be added.
[0049] As mentioned above, although the manufacture approach by the photopolymerization method was shown, microencapsulation liquid crystal can be formed also by the emulsion method. Moreover, the liquid crystal solidification object complex to which capsule particle diameter was mostly equal can also be formed using micro porous glass by pressing out a liquid crystal ingredient in the liquid of a capsule ****** ingredient from an almost uniform glass hole.
[0050] Below, the internal structure of the liquid crystal optical element 30 is explained. Front electrode 30A located in a 1st field (optical ON outgoing radiation side) side consists of transparent electrodes, such as ITO. And it is a side front substrate and frosting processing of the ITO interface of the glass substrate 31 is carried out beforehand. The irregularity formed of frosting processing should just be a configuration which reduces that the normal reflection by the interface finally reaches the optical fiber 50 by the side of outgoing radiation. Therefore, the irregularity of the shape of a rectangle in which many fields parallel to reflector 30C exist is unsuitable, and its irregularity of ** (serrate) which is the aggregate of the slant face which has a tilt angle is desirable.
[0051] Although this tilt angle is related to the effective diameter of an aperture diaphragm 14 and an optical fiber 50, the optical incident angle to flesh-side electrode 30C which is a reflector, etc., generally as unnecessary interface reflection as the irregularity of the shape of sharp ** is removed, so that a tilt angle is perpendicularly near. However, since surface area increases so that an acute angle, the rate of interface reflection increases and the transmitted light which can be used decreases. Therefore, the irregularity of the shape of ** with many inclination components which do not cause the remarkable decline in permeability but can reduce unnecessary interface reflection is desirable.
[0052] Moreover, in the property of the amount of transmitted lights over applied voltage, like [ in the case of an on-off control action ], when a sharper standup is needed, concavo-convex magnitude (pitch) is so desirable [ as a display device in this liquid crystal optical equipment, since the homogeneity of the property within a field is not required the constraint about concavo-convex magnitude (pitch) is not so severe, but ] that it is small. It is more desirable to make it into a big value, concavo-convex pitch, i.e., depth, and for the thickness of a liquid crystal solidification object complex layer to distribute on the other hand, since the property of the amount of transmitted lights over gently-sloping applied voltage is required for application of

the dimmer which wants to control the middle quantity of light finely.
[0053] Specifically, concavo-convex magnitude (pitch) has desirable about 2-200 micrometers. The concavo-convex depth Rz (ten-point average of roughness height) About 0.1-10 micrometers is desirable. Toothing voice reduces [ since, as for the case of rectangle-like irregularity, the area of a normal reflector is changeless / a part for interface reflective noise Mitsunari which carries out incidence to an outgoing radiation side fiber ] therefore has desirable ** (serrate).
[0054] in order to reduce further the interface reflectivity produced between the transparent electrodes and liquid crystal solidification object complex layers which were formed on the concave convex -- a transparent electrode layer top -- SiO2 MgF2 etc. -- it is desirable to form a low refractive-index layer as an antireflection film.
[0055] Moreover, un-transparence flesh-side electrode 30C which used also [ reflector ] and formed the aluminum film was formed on the glass substrate 32. The light reflex means which consists of liquid crystal solidification object complex layer 30B and flesh-side electrode 30C which achieve the function of light modulation by this configuration was able to make it stick. The dielectric multilayer reflecting mirror which also made flesh-side electrode 30C transparence, and carried out the laminating of the dielectric film with which refractive indexes differ relatively by the thickness of light wave length extent can be prepared in piles, and it can also consider as a light reflex means.
[0056] In this case, since it is hard compared with the aluminum reflective film, even if it uses the spacer for gap control of a liquid crystal solidification object complex layer, endurance surpasses that it is hard to attach a blemish. Moreover, while being able to design a reflection factor and a reflected wave length band to arbitration by changing the film configuration of dielectric multilayers, about 100% of high reflection factor is also obtained.
[0057] Incidence of the visible ray emitted from a halogen lamp is carried out to the liquid crystal optical element 30 through a reflecting mirror 14. And the alternating voltage which makes a 100Hz square wave a subcarrier was impressed to inter-electrode [ of a liquid crystal optical element ], and the liquid crystal optical equipment which has a modulated light function was obtained by modulating an effective voltage value by the external circuit, and changing the transparency dispersion condition of a liquid crystal optical element. The optical property of the liquid crystal optical equipment of this invention used combining an optical fiber, a plano-convex lens, the liquid crystal optical element of a transparency dispersion mold, etc. in this way was measured. The result was summarized in Table 1.
[0058] In Table 1, relative light transmittance makes the example of a comparison 100%. measurement -- constant temperature -- it is carried out within a degree tub and temperature shows not the temperature of the liquid crystal optical element itself but the ambient temperature of liquid crystal optical equipment. The measured extinction ratio shows the range of the applied-voltage value of the liquid crystal optical element in a 0 to 40 degrees C temperature requirement, and the light value ratio of the optical fiber 50 by the side of the outgoing radiation to 0V and 30V. As an example of a comparison, the ITO electrode surface by the side of the optical incidence of a liquid crystal optical element was formed into the flat side, same optical property evaluation was performed about the thing of a configuration of not giving a black-lacquered light absorption object to the convex of a plano-convex lens, and the result was indicated.
[0059]
[Table 1]

| | 構　成　内　容 | 相対的光透過率 | 消光比 | 応答速度（ｍｓｅｃ） |
|---|---|---|---|---|
| 実施例１ | 界面に凹凸あり、光吸収体あり | ９８％ | ３００～３５０ | ５ |
| 比較例１ | 界面に凹凸なし、光吸収体なし | １００％ | ３～　１５ | ３～２００ |

[0060] From this result, while there has almost been no optical loss by the configuration of this invention, the improvement in fast of an extinction ratio and repeatability of operation are improved. Therefore, by using the liquid crystal optical equipment of this invention as a dimmer etc., adjustment of the outgoing radiation quantity of light corresponding to an applied-voltage value does not almost have quantity of light loss, and can carry out to a high speed arbitrarily.
[0061] Moreover, the optical outgoing radiation edge of the optical fiber by the side of outgoing radiation is turned to an illuminated object, and the liquid crystal optical equipment of this invention installs it, and when carrying out optical high measurement of a S/N ratio by the lock-in amplifier, it can use the electrical signal of photodetectors, such as the photomultiplier tube and Si photodiode, as a required fiber type light chopper. Compared with a conventional pivoted window type chopper or a conventional oscillatory type chopper, small and high-speed optical chopping becomes possible.
[0062] Moreover, by incorporating with the image storage of image metering devices, such as a CCD camera, making it synchronize with timing, and carrying out the high-speed shutter ring of the liquid crystal optical element, high image measurement of a S/N ratio is attained, in application of obtaining the binarization processing image of the image after image measurement, a shape recognition, etc., it is highly precise, and high-speed processing is attained.
[0063] Moreover, when using the liquid crystal optical equipment of this example as a lighting system, generally a dark part tends to produce the light which outgoing radiation is carried out from a bundle fiber, and is emitted in the shape of a cone in an optical-axis core. This is because the light of the include-angle field of 10-degree or less extent runs short to an optical axis among the light which luminescence of the light source is the effect of the shade produced by the lamp tube wall or the filament, and carries out incidence to an aperture diaphragm. in order to improve such heterogeneity, it is effective to install cone-like prism or a cone-like reflector in an aperture-diaphragm location (the secondary focus of an ellipse mirror prepared in a light source system -- for a location to be corresponded to mostly), and to supply light to the include-angle field of 10-degree or less extent to an optical axis. This can attain equalization of the flux of light.
[0064] The configuration of the cone-like prism used here or a cone-like reflector becomes settled to the illuminance homogeneity of the exposure side to need with regards to luminous-intensity-distribution distribution of the light source, an ellipse mirror configuration, the focal distance of a plano-convex lens, its effective diameter, etc. When using cone-like prism, it is the concave cone-like prism whose convex cone object-like prism or vertical angle phi whose vertical angle theta by the side of the optical outgoing radiation is 90 degrees - 175 degrees is 185 degrees - 270 degrees, and, specifically, it is good to use with an aperture diaphragm (for the function that the electrode holder a formal aperture stop or for installation is also almost equivalent to be achieved).
[0065] An unnecessary light is removed by the aperture diaphragm and it is collected into equalization of the flux of light, and the one flux of light by cone-like prism. Since it is desirable to make it the size according to the aperture of the optical fiber for outgoing radiation used, the size of the flux of light is good to prepare the aperture diaphragm of a suitable dimension etc.
[0066] In the optical-communication field etc., when only the total light value of fiber outgoing

radiation light is needed and there is no constraint about the luminous-intensity-distribution angular distribution, it is equal, and when the incident light to a liquid crystal optical element is uniform, the orientation distribution of light by which outgoing radiation is carried out from the diameter of the light source does not need to install the component for equalization especially, and is good at an aperture diaphragm or a monotonous reflecting mirror.

[0067] On the contrary, distribution is [ whenever / orientation angle / of fiber outgoing radiation light ] uneven, and when the exposure section serves as ununiformity quantity of light distribution and poses a problem as a lighting system according to it, homogeneity distribution improves by using cone-like prism or a cone-like reflector. In the light source system using the ellipse mirror especially shown in the example as a converging mirror, since it is easy to produce a shadow in a core, cone-like prism or a cone-like reflector is effective. If cone-like prism is used combining an aperture diaphragm, a still better result will be obtained.

[0068] Moreover, when using a cone-like reflector, it is desirable that it is the concave reflector whose convex reflector or vertical angle gamma whose vertical angle beta of a reflector is 150 degrees - 177 degrees is 183 degrees - 210 degrees. Since the effective reflector product of itself achieves the same diaphragm function as an aperture diaphragm, this cone-like reflector is simple.

[0069] Although cone-like prism is not used near the secondary focus location, if this cone-like prism is further used together in this example When what was about 30% of the maximum illuminance within an exposure side forms the convex cone object-like prism whose vertical angle theta is 120 degrees, the illuminance in the optical-axis core of an optical fiber exposure side The illuminance in the optical-axis core of an exposure side turned into the maximum illuminance, the illumination distribution which carries out gently-sloping reduction was acquired in the radius vector direction, and illuminance homogeneity good as a lighting system with a high-speed modulated light function was acquired.

[0070] Moreover, when a plano-convex lens is used as a condensing means, it is desirable to paste up the convex of a lens with the binder with which air was faced and refractive-index matching was able to take the flat side to the glass substrate side of a liquid crystal optical element. At this time, the curvature part which produces and cheats out of the unnecessary normal reflection which surely carries out incidence to an outgoing radiation side optical fiber in the interface of the convex of a lens and air exists. If a light absorption object is prepared only in a part for this curvature surface part or the detailed irregularity for normal reflective reduction is formed, this interface reflection will be reduced.

[0071] Since the area in which a light absorption object is formed here is minute, the transmissibility of the light as the whole liquid crystal optical equipment is hardly influenced. Moreover, metallic reflection mirrors, such as aluminum, are sufficient as a reflector, and an optical interference multilayers reflecting mirror is sufficient as it. In the case of the former, in order that a reflector may serve also as an electrode, manufacture is easy, and a liquid crystal optical element can be constituted without complicating structure. In the case of the latter, it is also possible to form the cold mirror which has the spectral characteristic which penetrates a heat ray and reflects only the light by the configuration of optical interference multilayers, and it has the degree of freedom which can also form the mirror of 100% of reflection factors to the specific semiconductor laser wavelength used by optical communication.

[0072] By considering as the arrangement configuration of the light source optical system, the condensing means and liquid crystal optical element like this example, and the optical fiber for an output, the transfer loss to the bundle fiber which constitutes an optical fiber decreased, and the higher optical equipment of efficiency for light utilization was obtained. It became possible to use the light source of the large quantity of light especially, and it is low loss and precise optical control was attained.

[0073] In this example, although the bundle fiber was used as an optical fiber, a single fiber with big aperture is sufficient. Since there is no flexibility when the core section with a diameter of about 5mm is formed with glass, the structure which makes a clad air by using plastics and translucency rubber as a core is sufficient. In order to prevent the dirt of an interface with air, it is desirable to apply the fluororesin of a low refractive index to a front face.

[0074] Although photoconductive close effectiveness is bad since the occupancy area of the core part which light actually transmits is as low as 50 - 80% in the case of a bundle fiber, in the case of such a diameter core fiber of single track macrostomia, photoconductive close effectiveness is as high as 90% or more.

[0075] (Example 2) An example 2 is shown in drawing 2 . The liquid crystal optical equipment in this example has the almost same configuration as an example 1. The description here is that some interfaces of a liquid crystal optical element equipped with the function which has a reflective mold mode of operation and modulates light are slanting to an optical axis. Specifically, only whenever [ predetermined tilt-angle / alpha ] is formed [ the liquid crystal solidification object complex layer ] for the inclination to the perpendicular and flat light reflex means 90 to the symmetry axis of incident light and the reflected light.

[0076] The field of transparent two front electrode 30A which consists of ITO of a liquid crystal table optical element etc., and flesh-side electrode 30C is flat. And it is arranged so that the unnecessary reflected light generated from the interface of the liquid crystal solidification object complex layer 30B may carry out incidence to the optical fiber 50 by the side of outgoing radiation, and may not cause degradation of an extinction ratio, and liquid crystal solidification object complex layer 30B may incline to an optical path.

[0077] alpha should just be a value to which the normal reflection by that interface reduces reaching the optical fiber 50 by the side of outgoing radiation finally whenever [ this tilt-angle ]. What is necessary is just to specifically make the tilt angle alpha of liquid crystal solidification object complex into the big value from the point on the reflector in a light reflex means to the prospective angle when expecting the effective radius (it being the effective radius of the whole bundle fiber in the case of a bundle fiber) of an optical fiber.

[0078] Since the core diameter is as thin as 200 micrometers or less, the range of alpha of 0.1 degrees - 10 degrees is [ whenever / tilt-angle ] desirable in the case of the single track fiber for optical communication. Since it uses as a bundle fiber in the case of the fiber for optical energy transmissions, and the diameter of a fiber of the optical transmission section is as thick as about 2-20mm, 1 degree - about 20 degrees of alpha are [ whenever / tilt-angle ] on the other hand, desirable.

[0079] Furthermore, although the interface reflected light is removed also when it considers as whenever [ big tilt-angle ], the light which carries out incidence from across becomes most at a liquid crystal solidification object complex layer, and effectual permeability falls that it is easy to produce Hayes accompanying index mismatching at the time of transparence. Moreover, since a liquid crystal optical element will become thick and the magnitude and weight of the whole equipment will increase if alpha becomes large whenever [ tilt-angle ], limiting to the above-mentioned range is [ whenever / tilt-angle ] desirable [ alpha ].

[0080] In this example, since the effective radius of the bundle fiber 50 is 2.5 mm and the distance to a reflector 90 is about 50mm, a prospective angle becomes about 3 degrees. Therefore, it is enough if the tilt angle alpha of liquid crystal solidification object complex is made into 5 degrees in this case.

[0081] Light is reflected by the light reflex means 90 formed in the tooth back of a liquid crystal optical element. This is good at the aluminum film or other metal membranes. Or the cold mirror using the optical interference multilayers which reflect the light and penetrate infrared light is sufficient.

[0082] A heat regulator 60 can be formed in the flat side on the background of the light reflex means 90. Or after forming in the side face of prism 80 in which it has a small vertical angle corresponding to alpha whenever [ tilt-angle / to make / of liquid crystal solidification object complex layer 30B and the light reflex means 90 ], as a reflector, the liquid crystal optical element 30 and a heat regulator 60 may be pasted with optical adhesives. In order not to reduce permeability, the adhesion method which used the latter prism 80 is desirable.

[0083] In this example, in order to perform a temperature control to accuracy more and to secure the repeatability of an optical property also to large environmental temperature, the cold mirror was formed as a light reflex means 90, and the heat sink where the Peltier device and temperature sensor of electronics control were embedded as a heat regulator 60 was used.

[0084] When the configuration of an example 2 estimated the optical property, in the large environmental temperature of −20 to 80 degrees C, the property of an extinction ratio 350 was always shown, and the result of having been stabilized by the applied-voltage pair optical output property to the temperature change in coincidence was obtained. Moreover, compared with the aluminum reflecting mirror, since the reflection factor was high about 10%, the direction of a cold mirror of relative light transmittance was a high value compared with the example 1 of a comparison.
[0085] (Example 1 of reference) The example 1 of reference is shown in drawing 3 . In this example, an optical fiber is used for the both sides of I/O of light, and the edge of each optical fiber by the side of incidence and outgoing radiation is arranged near the center of curvature of the condensing means in an optical path. The conventional example (liquid crystal optical equipment which has two optical fibers shown in drawing 7 ) and basic arrangement which mentioned this arrangement above serve as almost same configuration. It is made to stick a plano-convex lens 40 to the side front of the liquid crystal optical element 30 through a glue line.

[0086] In this example 1 of reference, irregularity is prepared in the interface of one electrode 30A of the liquid crystal optical element 30. With this irregularity, unnecessary interface reflection of a liquid crystal optical element is removable. It is prepared almost in parallel by liquid crystal solidification object complex 30B and un-transparence flesh-side electrode 30C which is a light reflex means.
[0087] Furthermore, in the liquid crystal optical equipment of the example 1 of reference, it has composition which can carry out forcible temperature control of the liquid crystal optical element from a reflector side like examples 1 and 2. As a compulsive temperature control method, it equips with a heat sink and cools with an air cooling fan. Or it can equip with a Peltier device, an electrical heater, and a temperature sensor, and temperature control of heating and the cooling can also be performed and carried out so that it may be maintained by fixed temperature.
[0088] (Example 2 of reference) The example 2 of reference is shown in drawing 4 . Unlike the example 1 of reference, this liquid crystal optical equipment is made into the field where an electrode surface is flat. In this case, it is also possible to paste a reflector, after using not a glass substrate but a PET film with ITO for a substrate and forming a transparency mold component.
[0089] What is necessary is to just be mostly condensed by the location of the optical incidence edge of the optical fiber 52 for outgoing radiation which the light by which an aspheric lens is sufficient as and outgoing radiation was carried out from the optical fiber 51 for one incidence as a plano-convex lens 40 in addition to the spherical lens converges with the plano-convex lens 40 which is a condensing means, and has it in a conjugation-location in these examples of reference. The black coating of the shape of a spot with a diameter of about 1mm was applied to the core of a liquid crystal display component, the light absorption object 70 was established, and reflection of the part was lost so that interface reflection with the liquid crystal optical element 30 and the external worlds (filler gas inside air or a case etc.) might carry out incidence to the optical fiber 52 by the side of outgoing radiation and might not cause degradation of an extinction ratio.
[0090] Moreover, in order to raise permeability, the coat of the antireflection film has been carried out to convex surface 40a of a plano-convex lens 40. Also in these examples of reference, the heat sink was pasted up and the temperature control was performed by the same approach as an example 1.
[0091] When the configuration of the example 1 of reference and the example 2 of reference estimated the optical property, the example 1 and the evaluation result of an extinction ratio good almost similarly were obtained. In the above explanation, although it is pasting up and unifying after separating and producing a liquid crystal optical element and a plano-convex lens, electrodes, such as ITO, are directly formed in the flat side of a plano-convex lens, and it is good also considering itself as a counterelectrode substrate of one of the two of a liquid crystal display component.

[0092] (Example 3 of reference) Although it was the almost same configuration as the example 2 of reference of drawing 4 , the plastics aspheric surface plano-convex lens whose effective diameter the focal distance of the plano-convex lens which is a condensing means using the single track optical fiber for optical-communication information transmissions instead of the bundle fiber for energy transmission about the optical fiber by the side of incidence and outgoing radiation is 20mm, and is 10mm was used. Measuring area of a liquid crystal optical element was made into the larger configuration than the measuring area of a plano-convex lens.
[0093] The single track optical fiber used the compound glass fiber whose core which is the optical transmission section is the diameter of 200 micrometers. Moreover, the black painting of about 0.5 mm was formed in the center section of the convex of a plano-convex lens as a light absorption object. Other configurations presupposed that it is the same as the example 2 of reference. The used light source is semiconductor laser with an oscillation wavelength of 850nm, the dielectric multilayer reflecting mirror whose reflection factor of 850nm is 100% was formed in the reflector upwards, and the ITO film is formed as a transparent electrode.
[0094] As a result of this configuration's estimating an optical property, the property which an extinction ratio calls 5000 and a speed of response always calls 3msec(s) with the large environmental temperature of -20 degrees C - 80 degrees C was shown, and the result of having been stabilized by the applied-voltage pair optical output property to the temperature change in coincidence was obtained.
[0095] Thus, while there has almost been no optical loss by the configuration of the example of reference, the improvement in fast of an extinction ratio and stability are attained. Therefore, even if it is liquid crystal optical equipment of the example of reference, adjustment of the outgoing radiation quantity of light corresponding to an applied-voltage value can carry out to a high speed arbitrarily [ there is no quantity of light loss and ] by using as a good light variation attenuator for optical communication.
[0096] (Example 3) The block diagram of overall arrangement of an example 3 is shown in drawing 5 . the liquid crystal optical element 30 — the part — the expanded sectional view is shown. Although the basic configuration of a light source system was the same as the example 1, 150W and a metal halide lamp with an arc length of 5mm were used as the light source. Moreover, in the opening location of an aperture diaphragm 14, the diameter of 10mm and the cone-like reflector 13 by which the cold mirror was formed by the side face of cone-like prism in which the vertical angle beta was 160 degrees have been arranged, and two bisectrices of a vertical angle leaned 30 degrees of opticals axis, and have arranged. By using such a cone-like reflector 13, the illumination distribution of the incident light to the liquid crystal optical element 30 was equalized.
[0097] The liquid crystal optical element 30 in this example is considered as the electrode configuration which can impress and drive an electrical potential difference for every electrode pair with which it was divided into plurality so that the electrode which counters might become the same configuration, and each was divided. Moreover, a plano-convex lens is arranged by 1 to 1 in the shape of an array, and is made to stick to the front-face side of a liquid crystal optical element through a glue line for every electrode pair. Incidence is carried out to liquid crystal solidification object complex layer 30B by which the light which carried out incidence to the liquid crystal optical element was pinched by each electrode pair through each plano-convex lens from the optical light source system of the same configuration as an example 1.
[0098] It is reflected with the light reflex means (it is made to serve a double purpose for flesh-side electrode itself, or the reflector of dedication is formed in the background) formed in one electrode side (background) of liquid crystal solidification object complex layer 30B, and the reflected light is condensed by different location through the again same liquid crystal solidification object complex layer 30B and each plano-convex lens, and two or more generation of the conjugate image of the aperture diaphragm of the light source system corresponding to the number of plano-convex lenses is carried out. Since this conjugate image dissociates respectively and is formed corresponding to the number of each plano-convex lens, a condensing point is generated only for the number of electrode pairs divided as a result.
[0099] Two or more optical fibers which have an effective diameter corresponding to the

magnitude of a conjugate image at the condensing point that two or more of these conjugate images are formed are installed in an optical outgoing radiation side. Therefore, by controlling independently the high-frequency voltage impressed between each electrode pair, the dispersion condition of liquid crystal solidification object complex layer 30B between each electrode pair changes independently respectively, and can control independently the outgoing radiation quantity of light of two or more optical fibers by the side of outgoing radiation.
[0100] In this example, seven-piece (one core, six peripheries) contiguity of the electrode pair of a forward hexagon was carried out, it has been arranged, the electrode substrate which wired so that electrical-potential-difference impression could be carried out independently was prepared, front electrode 30A by the side of optical incidence considered as the frosting side in which the same irregularity as an example 1 was formed, and another flesh-side electrode 30C was taken as the aluminum electrode to serve also as a reflector.
[0101] And carried out impregnation exposure of the ingredient of the same liquid crystal solidification object complex as an example 1, the solidification object was made to harden, and the liquid crystal optical element 30 of a transparency dispersion mold was formed. Furthermore, the array of a plano-convex lens with a focal distance of 80mm was pasted up on each electrode pair with the forward hexagon corresponding to the configuration, and black painting with a diameter of about 2mm was given to the core of the convex of a lens as a light absorption object 70.
[0102] The top view which saw from the top the component with which the array of a liquid crystal optical element and a plano-convex lens was united is shown in drawing 6 . a part of liquid crystal optical element 30 shown in drawing 5 -- an expanded sectional view corresponds to the cutting plane of A-A'. In addition, the heat regulator 60 was considered as the same configuration as an example 1.
[0103] The distance of the cone-like reflector 13 of a light source system and the liquid crystal optical element 30 was taken about 120mm, and it has arranged so that about 10 degrees of opticals axis of the light which carries out incidence to the liquid crystal optical element 30 may incline. When the liquid crystal optical element 30 was transparence, the conjugate image of a cone-like reflector side was formed in the liquid crystal optical element and the location distant 60mm as a round shape of seven about 5mm diameters of the array of a plano-convex lens with a focal distance of 80mm, and the reflector of a liquid crystal optical element. A total of seven optical fibers with a diameter of 6mm was installed in each conjugate-image location.
[0104] The optical fiber used here used as the core of a 6.5 mm diameter the object into which the elastomer made from translucency silicone resin was processed in the shape of a rod, and what covered the fluororesin of a low refractive index as a clad on the periphery was used for it. Since an optical transmission loss becomes large compared with the bundle fiber which bundled and used the textile-glass-yarn optical fiber by using such a single track optical fiber, it is not suitable for long-distance transmission, but since core area can take greatly, and photoconductive close effectiveness is high, in the optical energy transmission which is 10m or less extent, low cost-ization of the whole transmission efficiency is attained highly.
[0105] While dividing the outgoing radiation light from the single light source into plurality efficiently and being able to carry out the light guide with the optical fiber by using the liquid crystal optical equipment of this example, the light of the quantity of light of the light by which a light guide is carried out with each optical fiber was able to be independently stabilized and modulated at the high speed. Therefore, if the liquid crystal optical equipment of this example is carried in an automobile, from the single light source, two or more optical fibers can divide, a light guide can be carried out, and it can use as a head lamp, a tail lamp, a tonneau light, and the light source for instrument panels. Moreover, it has a function suitable for the dynamic production of stage lighting or inside-of-a-shop lighting.
[0106] In the liquid crystal optical equipment of this example, modulated light of each colored light or modulated light of the color of arbitration is attained by combining the light from the single light source with color separation or the function which carries out color composition using a dichroic mirror.
[0107] Moreover, constitutionally, since [ of this invention ] a heat regulator can be installed in

one side of a liquid crystal optical element, by compulsory temperature control, it can maintain now at the temperature by which the optimal characteristics of a liquid crystal optical element are always discovered regardless of the quantity of light and the wavelength band which are used, or perimeter environmental temperature, and the stable modulated light or the stable optical shutter ring is obtained.
[0108] As mentioned above, although the example was explained, an approximate account is performed about the magnitude of each part etc. next. In transmitting light energy, a halogen lamp, a metal halide lamp, Xe lamp, etc. are used as the light source, and in order for all to condense efficiently using a condensing means and for luminescence length to do a light guide to a fiber about 2-10mm for a certain reason, the fiber diameter of about 3-10mm is needed.
[0109] Moreover, the magnitude of the light source has the width of face of 10-30cm (500W-3kW) extent from die length of 3-10cm (10W - 500W class), and the magnitude of a converging mirror will also be doubled according to the classification of the light source. Although the magnitude of a liquid crystal optical element is decided according to N.A. of the magnitude, for example, the focal distance and effective diameter, and the fibers of the condensing means to be used (an ellipse mirror, lens, etc.) etc., when using the above-mentioned light source, the thing of about 1-30cm of vertical angles is about used for it. In this invention, a high property can be attained irrespective of the magnitude of a liquid crystal panel.
[0110] In using for the purposes, such as a communication link and optical measurement, the incidence aperture of light is 1mm or less, and the diameter is set to 1cm or less even if it uses a lens, since the emission light of laser die auto or LED is condensed. Since the optical transmission section core diameter of the single track fiber for optical communication is 200-micrometer or less extent, the magnitude of a liquid crystal optical element is set to about about 1-5cm. Since semiconductor laser light etc. is used, light serves as almost single wavelength. Even in this case, the actuation by which the quantity of light was relatively stabilized with precise control as it is small is guaranteed.
[0111] (Example 4 of reference) The example 4 of reference is shown in drawing 8 . It is what improved further the example equipped with alpha whenever [ tilt-angle / which was mentioned above ], and is the example which gave whenever [ tilt-angle ] to the liquid crystal optical element using two wedge-shaped prism objects, and made parallel mostly the reflector and the flat side of a plano-convex lens. The property equivalent to the example mentioned above was acquired.
[0112]
[Effect of the Invention] According to the liquid crystal optical equipment of this invention, with the liquid crystal optical element and light reflex means which can control a dispersion condition and a transparency condition electrically, the condensing means, etc., in order to make the light modulation part of a liquid crystal optical element pass twice the light by which outgoing radiation was carried out from the light source, compared with the case where it penetrates only once, effectual scattering power improved by leaps and bounds.
[0113] Moreover, as an unnecessary normal reflected light reduction means [ whether irregularity is formed in the interface of a liquid crystal solidification object complex layer and a transparent electrode, and ] or to the pan which does not make parallel a liquid crystal solidification object complex layer and a reflector, but attaches an inclination By preparing a light absorption object in the interface reflector part which carries out incidence to a direct optical fiber without passing a liquid crystal solidification object complex layer in a component interface with air, the unnecessary interface reflected light which is the main factor of background noise has been reduced. Consequently, improvement in the extinction ratio in the good modulation light function according to applied voltage and its dynamic range was attained.
[0114] Moreover, constitutionally, since [ of this invention ] a heat regulator was installed in one side of a liquid crystal optical element, precise temperature control can be performed and it could maintain at the temperature by which the optimal characteristics of a liquid crystal optical element are always discovered regardless of the quantity of light and the wavelength band which are used, or perimeter environmental temperature. And even when carrying out propagation control of the light of the large quantity of light, the stable modulated light or the stable optical

shutter ring was obtained.
[0115] Moreover, there is stroboscope lighting as the light source for lighting which has a high-speed shutter function. High-speed photography is attained in this case. If the body which moves at the rate of 360 km/s is irradiated as a concrete example when shutter speed is 1ms, a 1cm moving-average image will be recorded.
[0116] Moreover, if shutter ring lighting is carried out continuously and a high-speed migration body is photoed, a locus will be recorded in the shape of a step.
[0117] Adjustable [ of the shutter timing ] could be carried out to arbitration, for example, advertising lighting, display object lighting, and floor lighting were mentioned as an example using the programmable special feature that high-speed flattery nature is, and more active lighting was attained a shutter ring or by modulating the light synchronizing with the strength of the sound of BGM, or a tone.
[0118] The control function of the light source for measurement turned on and off a fixed period was borne using this liquid crystal optical equipment as light source control for optical synchronous magnification detection (lock in amplifier), and high measurement of a S/N ratio was attained also in the environment with much a feeble signal light or noise light by amplifying and detecting only the signal light of the period.
[0119] Consequently, the liquid crystal optical equipment of this invention can be used now for optical measurement as a lighting system with a modulated light function, or a lighting system with an optical shutter ring function.
[0120] The S/N ratio has been improved by taking photodetection equipment and a synchronization like the light chopper for lock in amplifier, and performing a shutter ring especially. Moreover, also in the optical-communication field, the strange optical attenuator which can be decreased can be obtained now by applied-voltage adjustment instead of the optical attenuator of a fixed attenuation factor used conventionally.
[0121] Moreover, it approaches and the liquid crystal optical element which has a light modulation function for the mass light source especially is prepared, precisely, it is stabilized and light with strong reinforcement can be controlled.
[0122] Moreover, this invention is suitable for application various in the range which does not lose the effectiveness.

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[Translation done.]

## TECHNICAL FIELD

[Industrial Application] This invention relates to the liquid crystal optical equipment using an optical fiber and the liquid crystal optical element of the transparency dispersion mold equipped with liquid crystal solidification object complex, and the lighting system using it.

[Translation done.]

## PRIOR ART

[Description of the Prior Art] A liquid crystal optical element is arranged between the light source and the optical fiber for optical transmissions from the former, and the liquid crystal optical equipment which controls the quantity of light transmitted to an optical fiber from the light source by the liquid crystal optical element is known. Furthermore, the lighting system and luminous-intensity-distribution equipment using the bundle fiber, the light source, and the liquid crystal optical element which bundled the optical fiber for optical energy transmissions or the optical fiber of single track are proposed.
[0003] Moreover, an optical fiber is used for the light guide means from the light source to a liquid crystal optical element, and the configuration which has arranged the liquid crystal optical element between optical fibers is proposed. The basic arrangement is shown in drawing 7 as a conventional example. The optical fiber 51 for incidence, the optical fiber 52 for outgoing radiation, a convex lens 41, and the liquid crystal optical element 30 in reflective mode separate spatially, and are arranged. Furthermore, the liquid crystal optical element 30 has a liquid crystal solidification object complex layer as electro-optics-stratum functionale in the interior, and shows the mode of operation of a transparency dispersion mold. And this configuration attains the modulation of light.
[0004] Moreover, although it is the arrangement configuration which resembled this conventional example, the optical variable attenuator which used the low loss thin line optical fiber for optical-communication information transmissions for the optical optical incidence [ of a liquid crystal optical element ] and outgoing radiation side is proposed. As mentioned above, since reduction of optical loss is attained by using the liquid crystal optical element equipped with the liquid crystal solidification object complex which has the mode of operation of a transparency dispersion mold, and can control light without a polarizing plate, even if it uses a high-reflective-liquid-crystal optical element and a lens, it is proposed that optical variable attenuator can be built.

[Translation done.]

## EFFECT OF THE INVENTION

[Effect of the Invention] According to the liquid crystal optical equipment of this invention, with the liquid crystal optical element and light reflex means which can control a dispersion condition and a transparency condition electrically, the condensing means, etc., in order to make the light modulation part of a liquid crystal optical element pass twice the light by which outgoing radiation was carried out from the light source, compared with the case where it penetrates only once, effectual scattering power improved by leaps and bounds.
[0113] Moreover, or [ forming irregularity in the interface of a liquid crystal solidification object complex layer and a transparent electrode as an unnecessary normal reflected light reduction means ], Or the unnecessary interface reflected light which is the main factor of background noise has been reduced by preparing a light absorption object in the interface reflector part which does not make parallel a liquid crystal solidification object complex layer and a reflector, but attaches an inclination and which carries out incidence to a direct optical fiber further without passing a liquid crystal solidification object complex layer in a component interface with air. Consequently, improvement in the extinction ratio in the good modulation light function according to applied voltage and its dynamic range was attained.
[0114] Moreover, constitutionally, since [ of this invention ] a heat regulator was installed in one side of a liquid crystal optical element, precise temperature control can be performed and it could maintain at the temperature by which the optimal characteristics of a liquid crystal optical element are always discovered regardless of the quantity of light and the wavelength band which are used, or perimeter environmental temperature. And even when carrying out propagation control of the light of the large quantity of light, the stable modulated light or the stable optical shutter ring was obtained.
[0115] Moreover, there is stroboscope lighting as the light source for lighting which has a high-speed shutter function. High-speed photography is attained in this case. If the body which moves at the rate of 360 km/s is irradiated as a concrete example when shutter speed is 1ms, a 1cm moving-average image will be recorded.
[0116] Moreover, if shutter ring lighting is carried out continuously and a high-speed migration body is photoed, a locus will be recorded in the shape of a step.
[0117] Adjustable [ of the shutter timing ] could be carried out to arbitration, for example, advertising lighting, display object lighting, and floor lighting were mentioned as an example using the programmable special feature that high-speed flattery nature is, and more active lighting was attained a shutter ring or by modulating the light synchronizing with the strength of the sound of BGM, or a tone.
[0118] The control function of the light source for measurement turned on and off a fixed period was borne using this liquid crystal optical equipment as light source control for optical synchronous magnification detection (lock in amplifier), and high measurement of a S/N ratio was attained also in the environment with much a feeble signal light or noise light by amplifying and detecting only the signal light of the period.
[0119] Consequently, the liquid crystal optical equipment of this invention can be used now for optical measurement as a lighting system with a modulated light function, or a lighting system with an optical shutter ring function.

[0120] The S/N ratio has been improved by taking photodetection equipment and a synchronization like the light chopper for lock in amplifier, and performing a shutter ring especially. Moreover, also in the optical-communication field, the strange optical attenuator which can be decreased can be obtained now by applied-voltage adjustment instead of the optical attenuator of a fixed attenuation factor used conventionally.

[0121] Moreover, it approaches and the liquid crystal optical element which has a light modulation function for the mass light source especially is prepared, precisely, it is stabilized and light with strong reinforcement can be controlled.

[0122] Moreover, this invention is suitable for application various in the range which does not lose the effectiveness.

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[Translation done.]

## TECHNICAL PROBLEM

[Problem(s) to be Solved by the Invention] In this case, in order that light may pass a liquid crystal solidification object complex layer twice by considering as the configuration of a reflective mold, the scattering power of the liquid crystal solidification object complex itself improves by leaps and bounds compared with the configuration of the transparency mold which light passes once.
[0006] However, in order for a part of interface reflection produced in the interface of a liquid crystal optical element, the interface of the lens for condensing, etc. to always carry out incidence to the optical fiber by the side of optical outgoing radiation, when liquid crystal solidification object complex was in a dispersion condition, the outgoing radiation quantity of light from an optical fiber did not become low, and the extinction ratio of the outgoing radiation light by the electrical-potential-difference impression to a liquid crystal solidification object complex layer and un-impressing was not able to say that it was high compared with the configuration of a transparency mold.
[0007] Therefore, the dynamic range of the quantity of light change accompanying electrical-potential-difference impression of a liquid crystal optical element hardly improved as compared with the component configuration of a transparency mold, and it was still a low characteristic value. Moreover, when the light source which emits a lot of light was used, it was remarkable, the repeatability of various kinds of electro-optics properties (the property of applied-voltage pair light transmittance, a dynamic response characteristic, extinction ratio, etc.) became low, and exact modulated light of the temperature rise of the liquid crystal optical element accompanying the radiant heat etc. was not completed.
[0008] Moreover, the outgoing radiation light from the light source was condensed in the ellipse mirror, and in the case of the lighting system which finally obtains outgoing radiation light from an optical fiber, the field where an illuminance is low was generated in the center section of the exposure side, and it had become a problem as a homogeneity lighting system. For example, since judgment precision would fall if it puts on the test equipment which performs a binarization image processing and judges the quality of mounting and the homogeneity within a field of exposure light is inferior after irradiating the outgoing radiation light from an optical fiber and inputting the image into the circuit board in which electronic parts were mounted with a CCD camera, it had become a problem.

[Translation done.]

## MEANS

[Means for Solving the Problem] This invention between the substrates of a pair with an electrode with the light source and a condensing means, respectively The liquid crystal solidification object complex with which distributed maintenance of the liquid crystal was carried out into the solidification object matrix is pinched. Light is scattered about, in case liquid crystal is controlled by the electric field generated in inter-electrode and the refractive index of liquid crystal is not in agreement with the refractive index of a solidification object matrix. The liquid crystal optical element equipped with the liquid crystal solidification object complex layer which light penetrates when the refractive index of liquid crystal was mostly in agreement with the refractive index of a solidification object matrix, A light reflex means and an optical fiber are prepared, and it is prepared so that a light reflex means may bend an optical path in the middle of the optical path from the light source to an optical fiber. A liquid crystal optical element is arranged at the reflector side of a light reflex means, and the light by which outgoing radiation was carried out from the light source is made to pass a condensing means. Furthermore, incidence is carried out from the 1st field of a liquid crystal optical element, and it is made to pass a liquid crystal solidification object complex layer. Furthermore it results in a light reflex means, is reflected with a light reflex means, and is made to pass a liquid crystal solidification object complex layer. Outgoing radiation is carried out from said 1st field of a liquid crystal optical element, and it is made to pass a condensing means. In the liquid crystal optical equipment by which the quantity of light which is mostly condensed by the optical input edge of an optical fiber, and is transmitted to an optical fiber from the light source by transparency and dispersion of the light in a liquid crystal optical element is controlled A light reflex means is approached or stuck by the liquid crystal solidification object complex layer, and a condensing means consists of a plano-convex lens. [ whether this plano-convex lens is prepared in contact with said 1st field of a liquid crystal optical element, and irregularity is prepared in at least one interface among the interfaces which exist in an optical path until it results / from the light source / in an optical fiber, and ] The liquid crystal optical equipment (1) characterized by making at least one interface incline only in only whenever [ predetermined tilt-angle / alpha ] to a light reflex means is offered.
[0010] Moreover, in the liquid crystal optical equipment (1) with which irregularity was prepared in this interface, the liquid crystal optical equipment (2) characterized by forming irregularity in one [ at least ] electrode surface of a liquid crystal optical element is offered. Moreover, in the liquid crystal optical equipment (1) with which only whenever [ this tilt angle / alpha ] was made to incline, alpha offers the liquid crystal optical equipment (3) characterized by consider as a bigger value than the prospective angle when expect the effective radius of an optical fiber from the point on the reflector in a light reflex means whenever [ tilt angle ].
[0011] Moreover, in any one of the above liquid crystal optical equipment (1) - (3), the liquid crystal optical equipment (4) characterized by preparing a light absorption object or scatterer in the part on the convex of a plano-convex lens is offered.
[0012] Moreover, in any one of the above liquid crystal optical equipment (1) - (4), the liquid crystal optical equipment (5) characterized by forming a heat regulator in the substrate side with which the light reflex means of a liquid crystal optical element was established further is offered.

[0013] Moreover, in any one of the above liquid crystal optical equipment (1) - (5), the liquid crystal optical equipment (6) characterized by coming to prepare an ellipse mirror further as a light guide means from the light source to a liquid crystal optical element is offered.
[0014] Moreover, in above liquid crystal optical equipment (6), the light source is arranged near the primary focus of an ellipse mirror. [ whether cone-like prism and an aperture diaphragm are put together and arranged as a condensing equalization means near the secondary focus of an ellipse mirror, and ] Or a cone-like reflector is arranged, the outgoing radiation light from the light source is condensed near the secondary focus in an ellipse mirror, and the liquid crystal optical equipment (7) characterized by the flux of light converged and equalized by said condensing equalization means carrying out incidence to a liquid crystal optical element further is offered.
[0015] Moreover, in above liquid crystal optical equipment (7), the liquid crystal optical equipment (8) characterized by considering as the convex cone object-like prism whose vertical angle theta by the side of the optical outgoing radiation of cone-like prism is 90 degrees - 175 degrees, or the convex cone object-like prism whose vertical angle phi is 185 degrees - 270 degrees is offered.
[0016] Moreover, in above liquid crystal optical equipment (7), the liquid crystal optical equipment (9) characterized by considering as the convex reflector whose vertical angle beta of the reflector of a cone-like reflector is 150 degrees - 177 degrees, or the concave reflector whose vertical angle gamma is 183 degrees - 210 degrees is offered.
[0017] Furthermore, the lighting system equipped with any one of the above liquid crystal optical equipment (1) - (9) is offered.
[0018] In the liquid crystal optical equipment of this invention, it is detailed irregularity's specifically being formed in one [ at least ] transparent electrode surface of a liquid crystal optical element as an unnecessary normal reflected light reduction means, or making the liquid crystal solidification object complex layer of a liquid crystal optical element incline to a light reflex means, and preparing, and the unnecessary normal reflected light produced in the interface of a liquid crystal solidification object complex layer and transparent substrate glass with an electrode etc. is reduced.
[0019] Moreover, one-structure is adopted and a compact, the liquid crystal optical equipment which was optically [ firmly and ] excellent mechanically, and a lighting system are offered so that the unnecessary normal reflected light by the interface between a condensing means and a liquid crystal optical element may be controlled positively.
[0020] Moreover, in the liquid crystal optical equipment of this invention, an ellipse mirror is first adopted as a light guide means from the light source to a liquid crystal optical element, and a condensing equalization means is established further. The light source is arranged near the primary focus of an ellipse mirror, and an aperture diaphragm, cone-like prism, or a cone-like reflector is arranged in the location near the secondary focus. It is easy to attain the function that an aperture diaphragm is equivalent in addition to a perfect aperture stop here. Simply, the electrode holder of cone-like prism also functions as an aperture diaphragm. Furthermore, it is effective, if black painting is carried out or it is delustered. It is good to use a formal aperture stop preferably.
[0021] Incidence of the light which the outgoing radiation light from the light source was condensed in the ellipse mirror by the location near the secondary focus, and was equalized as about one flux of light with the condensing equalization means is carried out by this configuration to a liquid crystal optical element. In this case, it is possible by using cone-like prism and an aperture diaphragm, or a cone-like reflector to equalize the luminous-intensity-distribution distribution of light by which outgoing radiation is carried out from an optical fiber as a condensing equalization means which is the component of a light guide means. And the optical fiber shutter for optical energy transmissions (lighting system) is offered, for example.

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[Translation done.]

## OPERATION

[Function] According to this invention, the light guide also of the strong flux of light by which outgoing radiation was carried out from the light source, and the thick flux of light or the flux of light of single wavelength is carried out to a precision, and it is made to transmit to an optical fiber. In order that light may pass a liquid crystal solidification object complex layer twice at this time, the effectual scattering power of a transparency dispersion mold optical element improves. And by making an unnecessary normal reflected light component reduce positively, a noise component is made to reduce greatly and light with strong reinforcement is also correctly transmitted by low loss. Consequently, degradation of an extinction ratio and a dynamic range which were looked at by the conventional example is improved, and transfer control of light with strong reinforcement is attained.
[0023] Moreover, without having direct effect on the light on an optical path until it results [ from the incidence to the liquid crystal optical element of light ] in outgoing radiation, when a heat regulator is formed in the rear face of a liquid crystal optical element, it becomes possible to carry out temperature control of the liquid crystal optical element compulsorily, and the electro-optics property of a liquid crystal optical element is stabilized extremely. Furthermore, precise transfer control of light with strong reinforcement can be attained. Hereafter, an example explains this invention concretely.

[Translation done.]

EXAMPLE

[Example]
(Example 1) The example 1 of this invention is shown in drawing 1 . As for the liquid crystal optical equipment of this invention, the ellipse mirror 12, the light source 11, and an aperture diaphragm 14 are used as light source optical system. In this example, the light source 11 is formed in the location almost near the 1st focus of the ellipse mirror 12, and the aperture diaphragm 14 is formed in the location almost near the 2nd focus of the ellipse mirror 12. The halogen lamp is used as the light source 11. Here, the filament part of a halogen lamp is installed in the location of the 1st focus, and the circular aperture diaphragm 14 is installed near the 2nd focus. Of course, the light-emitting part of a filament part has the volume which exists spatially, and is not the perfect point light source.
[0025] The optical fiber 50 which outputs light is arranged, and are the side front of the liquid crystal optical element 30 and the liquid crystal optical element 30 which has the reflective mold mode of operation which performs light modulation, and a plano-convex lens 40 is formed in contact with the close outgoing radiation side of light, and the 1st becoming field. In contact with the 2nd field, a heat regulator 60 is formed in the background of the liquid crystal optical element 30, and it consists of a drive circuit (illustration is omitted) which drives the liquid crystal optical element 30 further, an electrical circuit which carries out drive control of the heat regulator 60.
[0026] This heat regulator 60 is located in the background of a substrate 32, and pastes up the heat sink in which the thermo sensor and the electrical heater were built. Furthermore, the fan for air cooling was attached behind this heat regulator 60, and it could be made to carry out by the electrical heater and the fan for air cooling the temperature control, acting as the monitor of the temperature so that the liquid crystal optical element 30 may be maintained by laying temperature. Each of these components are dedicated to a case and cooled by air-conditioning by the fixed air flow.
[0027] What bundled the fiber of the numerical aperture (N.A.) 0.57 which uses multicomponent system glass as a core with a diameter of 50 micrometers, and was used as the bundle fiber with a diameter of 5mm was used for the optical fiber 50 by the side of optical outgoing radiation. It arranges in the location at which the main normal reflected lights arrive, and the circular aperture diaphragm 14 and the core of the end face of an optical fiber 50 (bundle fiber) are respectively installed in physical relationship [ **** ] mutually optically near the focal location of a plano-convex lens so that light may carry out incidence by eight incident angles to liquid crystal solidification object complex layer 30B of the liquid crystal optical element 30 respectively.
[0028] The focal distance is 50mm and the plano-convex lens 40 was pasted up on the 1st field (side front) of the liquid crystal optical element 30 with optical adhesives (illustration is omitted). Moreover, the coat of the antireflection film was carried out to convex surface 40a of a plano-convex lens 40, further, the black coating was applied to the form of the shape of a spot with a diameter of about 5mm, the light absorption object 70 was formed in the core, and reflection of the part was lost.
[0029] A suitable value exists with regards to the effective diameter of the optical fiber 50 which uses the formation location and area of a black coating, and the convex configuration of a lens. It

is desirable to form in the normal reflective location of lens convex surface 40a in which the reflected light in the convex of a lens carries out incidence to the optical fiber by the side of outgoing radiation. Although a black coating is applied to a part of convex surface 40a of a lens, the light absorption object 70 is formed and the unnecessary interface reflective component is reduced in this example instead, irregularity may be formed in the same field, scatterer may be prepared, and unnecessary normal reflection may be reduced.

[0030] The reflector of the ellipse mirror 12 was used as the cold mirror. The conjugate image corresponding to the effective diameter of the optical fiber 50 which is a bundle fiber makes the diameter of the aperture diaphragm 14 installed near the 2nd focus of the ellipse mirror 12 the configuration comparable as the conjugate image in the location by which image formation is carried out with reflexible flesh-side electrode 30C and the reflexible plano-convex lens 40 of the liquid crystal optical element 30.

[0031] By this example, since the conjugate image was formed at the rate of actual size, specifically, opening with a same as an aperture diaphragm 14 diameter [ as an outgoing radiation side bundle fiber ] of 5mm was installed. Moreover, the glass filter which has the spectral characteristic which absorbs or reflects ultraviolet rays and a heat ray was installed in this opening so that the ultraviolet rays and the heat ray which are contained during lamp luminescence might not carry out incidence to a liquid crystal optical element.

[0032] Only the light which the light by which outgoing radiation was carried out from the light source 11 was condensed in the ellipse mirror 12, and passed the aperture diaphragm 14 progresses to a plano-convex lens 40. Incidence is carried out from convex surface 40a of a plano-convex lens 40, and it is made to be refracted and progresses to the liquid crystal optical element 30. Furthermore, incidence is carried out to the liquid crystal optical element 30, and front electrode 30A in it and liquid crystal solidification object complex layer 30B are passed, and it reflects here in un-transparence flesh-side electrode 30C which is also an electrode and is also a light reflex means while remaining.

[0033] And liquid crystal solidification object complex layer 30B and front electrode 30A are passed again, a plano-convex lens 40 is passed further, and outgoing radiation is carried out from the convex surface 40a, and it is refracted and goes to the optical incidence edge of optical fiber 50 **. And it converges mostly in the location of this optical incidence edge, and incidence is carried out to an optical fiber 50. Next, it outlines about the configuration of the liquid crystal solidification object complex used by this invention.

[0034] In the liquid crystal optical element in this invention, the liquid crystal display component which pinched the liquid crystal solidification object complex with which distributed maintenance of the nematic liquid crystal was carried out into the solidification object matrix is used. It is desirable to use the liquid crystal solidification object complex it was made mostly in agreement [ complex ] with the Tsunemitsu refractive index (no) of the liquid crystal which distributed maintenance of the nematic liquid crystal which has a forward dielectric anisotropy especially is carried out into a solidification object matrix, and the refractive index of the solidification object matrix uses. And liquid crystal solidification object complex is pinched between substrates with the electrode of a pair.

[0035] no of a nematic liquid crystal When the refractive-index anisotropy which is a difference with an extraordinary index (ne) is set to **n, as for **n, it is desirable that it is 0.18 or more. Moreover, in order to obtain scattering power with a high liquid crystal solidification object complex layer to the specific wavelength lambda (micrometer), it is desirable that the mean particle diameter R of liquid crystal (micrometer) has gathered according to the wavelength. In fact, it is desirable to fill the relation of ** n-R**lambda.

[0036] Therefore, when modulating the light of the wavelength band (lambda=0.4-0.7 (micrometer)) of the light using the bundle fiber for optical energy transmissions, in order for the scattering power in a liquid crystal solidification object complex layer to become homogeneity mostly in a full wave length region, it is desirable to be distributed over the range in which the mean particle diameter R of liquid crystal fills the relation of 0.4<**n-R<0.7.

[0037] When, using the light of the semiconductor laser diode of a non-light region, or the single wavelength of the near-infrared wavelength region (lambda=0.8-1.6 (micrometer)) of LED as a

light on the other hand using the single track fiber for optical communication, or when using for optical measurement the light of the single wavelength of the helium-Ne laser which is the laser of a light oscillation, or semiconductor laser, the mean particle diameter R of liquid crystal has the desirable structure with little particle size distribution where ** n-R**lambda is filled.
[0038] As for the substrate with this electrode, that by which the electrode was prepared on substrates, such as glass, plastics, and a ceramic, is used. The configuration could be fixed and a substrate may be a flexible substrate like plastic film. Moreover, the substrate which has the spectral characteristic which absorbs or reflects ultraviolet absorption, infrared absorption, or an unnecessary wavelength component may be used.
[0039] A transparent ingredient is used for the substrate by the side of plane of incidence at least in this invention. Glass is suitable for forming few still flatter and optical distorted substrate sides.
[0040] Between the substrates of a pair with an electrode, liquid crystal solidification object complex is pinched, respectively. Electric field occur by impression of an electrical potential difference, this liquid crystal solidification object complex changes the orientation of a liquid crystal molecule according to that electric field, and the refractive index of the liquid crystal in liquid crystal solidification object complex changes. When the refractive index of the solidification object matrix is mostly in agreement with the refractive index of liquid crystal, light penetrates, and light is scattered about when not in agreement. Since the liquid crystal optical element using this liquid crystal solidification object complex does not use the polarizing plate, an optical modulator with little optical loss is obtained.
[0041] The liquid crystal solidification object complex which specifically consists of a solidification object matrix by which a large number formation of the hole fine as a liquid crystal display component was carried out, and a nematic liquid crystal with which the part of the hole was filled up is used. This liquid crystal solidification object complex is pinched between electrode substrates. The refractive index of the liquid crystal changes and the relation between the refractive index of a solidification object matrix and the refractive index of liquid crystal changes with the impression conditions of an electrical potential difference inter-electrode [ the ]. When these both refractive index is mostly in agreement, it will be in a transparency condition, and when refractive indexes differ, a liquid crystal optical element which will be in a dispersion condition can be used.
[0042] The liquid crystal solidification object complex which consists of a solidification object matrix by which a large number formation of this fine hole was carried out, and liquid crystal with which the part of that hole was filled up is the structure by which liquid crystal was confined in a liquid bubble like a microcapsule. However, each microcapsule does not need to be independent completely and the liquid bubble of each liquid crystal may be open for free passage through a slit like a porous body. Furthermore, the degree of a free passage may be high and in the condition which liquid crystal is opening for free passage in the shape of a stitch is sufficient.
[0043] The liquid crystal solidification object complex used for this invention is the following, and is made and manufactured. A nematic liquid crystal and the hardenability compound which constitutes a solidification object matrix are mixed, and it is made the shape of the shape of a solution, and a latex. Subsequently, what is necessary is for photo-curing, heat curing, hardening by solvent removal, reaction hardening, etc. to carry out this, to separate a solidification object matrix, and just to take the condition that the nematic liquid crystal distributed in the solidification object matrix.
[0044] Since the hardenability compound to be used can be hardened within a sealing system by making it photo-curing or a heat-curing type, it is desirable. When a photo-curing type hardenability compound is used especially, it cannot be influenced by heat, can be made to harden for a short time, and is desirable.
[0045] After forming a cel using a sealant like the conventional usual nematic liquid crystal as a concrete process, pouring in non-hardened mixture [ compound / a nematic liquid crystal and / hardenability ] from an inlet and closing an inlet, it can heat whether an optical exposure is carried out and can also be made to harden.
[0046] Moreover, in the case of the liquid crystal optical element in this invention, not using a

sealant, non-hardened mixture [ compound / a nematic liquid crystal and / hardenability ] can be supplied on the substrate which prepared the reflector as a counterelectrode, and the substrate which prepared another transparent electrode can also be stiffened by optical exposure etc. in piles after that.
[0047] Of course, after that, a sealant may be applied on the outskirts and the seal of the circumference may be carried out. According to this process, in order for what is necessary to be just to only supply a roll coat, a spin coat, printing, spreading according non-hardened mixture [ compound / a nematic liquid crystal and / hardenability ] to a dispenser, etc., an impregnation process is simple and productivity is very good.
[0048] Moreover, into non-hardened mixture [ compounds / these / nematic liquid crystals and hardenability compounds ], spacers, such as a ceramic particle for substrate gap control, a plastics particle, and a glass fiber, a pigment, coloring matter, a viscosity controlling agent, and the other additives that do not have a bad influence on the engine performance of this invention may be added.
[0049] As mentioned above, although the manufacture approach by the photopolymerization method was shown, microencapsulation liquid crystal can be formed also by the emulsion method. Moreover, the liquid crystal solidification object complex to which capsule particle diameter was mostly equal can also be formed using micro porous glass by pressing out a liquid crystal ingredient in the liquid of a capsule ****** ingredient from an almost uniform glass hole.
[0050] Below, the internal structure of the liquid crystal optical element 30 is explained. Front electrode 30A located in a 1st field (optical ON outgoing radiation side) side consists of transparent electrodes, such as ITO. And it is a side front substrate and frosting processing of the ITO interface of the glass substrate 31 is carried out beforehand. The irregularity formed of frosting processing should just be a configuration which reduces that the normal reflection by the interface finally reaches the optical fiber 50 by the side of outgoing radiation. Therefore, the irregularity of the shape of a rectangle in which many fields parallel to reflector 30C exist is unsuitable, and its irregularity of ** (serrate) which is the aggregate of the slant face which has a tilt angle is desirable.
[0051] Although this tilt angle is related to the effective diameter of an aperture diaphragm 14 and an optical fiber 50, the optical incident angle to flesh-side electrode 30C which is a reflector, etc., generally as unnecessary interface reflection as the irregularity of the shape of sharp ** is removed, so that a tilt angle is perpendicularly near. However, since surface area increases so that an acute angle, the rate of interface reflection increases and the transmitted light which can be used decreases. Therefore, the irregularity of the shape of ** with many inclination components which do not cause the remarkable decline in permeability but can reduce unnecessary interface reflection is desirable.
[0052] Moreover, in the property of the amount of transmitted lights over applied voltage, like [ in the case of an on-off control action ], when a sharper standup is needed, concavo-convex magnitude (pitch) is so desirable [ as a display device in this liquid crystal optical equipment, since the homogeneity of the property within a field is not required the constraint about concavo-convex magnitude (pitch) is not so severe, but ] that it is small. It is more desirable to make it into a big value, concavo-convex pitch, i.e., depth, and for the thickness of a liquid crystal solidification object complex layer to distribute on the other hand, since the property of the amount of transmitted lights over gently-sloping applied voltage is required for application of the dimmer which wants to control the middle quantity of light finely.
[0053] Specifically, concavo-convex magnitude (pitch) has desirable about 2-200 micrometers. The concavo-convex depth Rz (ten-point average of roughness height) About 0.1-10 micrometers is desirable. Toothing voice reduces [ since, as for the case of rectangle-like irregularity, the area of a normal reflector is changeless / a part for interface reflective noise Mitsunari which carries out incidence to an outgoing radiation side fiber ] therefore has desirable ** (serrate).
[0054] in order to reduce further the interface reflectivity produced between the transparent electrodes and liquid crystal solidification object complex layers which were formed on the concave convex — a transparent electrode layer top — SiO2 MgF2 etc. — it is desirable to

form a low refractive-index layer as an antireflection film.
[0055] Moreover, un-transparence flesh-side electrode 30C which used also [ reflector ] and formed the aluminum film was formed on the glass substrate 32. The light reflex means which consists of liquid crystal solidification object complex layer 30B and flesh-side electrode 30C which achieve the function of light modulation by this configuration was able to make it stick. The dielectric multilayer reflecting mirror which also made flesh-side electrode 30C transparence, and carried out the laminating of the dielectric film with which refractive indexes differ relatively by the thickness of light wave length extent can be prepared in piles, and it can also consider as a light reflex means.
[0056] In this case, since it is hard compared with the aluminum reflective film, even if it uses the spacer for gap control of a liquid crystal solidification object complex layer, endurance surpasses that it is hard to attach a blemish. Moreover, while being able to design a reflection factor and a reflected wave length band to arbitration by changing the film configuration of dielectric multilayers, about 100% of high reflection factor is also obtained.
[0057] Incidence of the visible ray emitted from a halogen lamp is carried out to the liquid crystal optical element 30 through a reflecting mirror 14. And the alternating voltage which makes a 100Hz square wave a subcarrier was impressed to inter-electrode [ of a liquid crystal optical element ], and the liquid crystal optical equipment which has a modulated light function was obtained by modulating an effective voltage value by the external circuit, and changing the transparency dispersion condition of a liquid crystal optical element. The optical property of the liquid crystal optical equipment of this invention used combining an optical fiber, a plano-convex lens, the liquid crystal optical element of a transparency dispersion mold, etc. in this way was measured. The result was summarized in Table 1.
[0058] In Table 1, relative light transmittance makes the example of a comparison 100%. measurement — constant temperature — it is carried out within a degree tub and temperature shows not the temperature of the liquid crystal optical element itself but the ambient temperature of liquid crystal optical equipment. The measured extinction ratio shows the range of the applied-voltage value of the liquid crystal optical element in a 0 to 40 degrees C temperature requirement, and the light value ratio of the optical fiber 50 by the side of the outgoing radiation to 0V and 30V. As an example of a comparison, the ITO electrode surface by the side of the optical incidence of a liquid crystal optical element was formed into the flat side, same optical property evaluation was performed about the thing of a configuration of not giving a black-lacquered light absorption object to the convex of a plano-convex lens, and the result was indicated.
[0059]
[Table 1]

| | 構　成　内　容 | 相対的光透過率 | 消光比 | 応答速度（ｍｓｅｃ） |
|---|---|---|---|---|
| 実施例１ | 界面に凹凸あり、光吸収体あり | ９８％ | ３００～３５０ | ５ |
| 比較例１ | 界面に凹凸なし、光吸収体なし | １００％ | ３～　１５ | ３～２００ |

[0060] From this result, while there has almost been no optical loss by the configuration of this invention, the improvement in fast of an extinction ratio and repeatability of operation are improved. Therefore, by using the liquid crystal optical equipment of this invention as a dimmer etc., adjustment of the outgoing radiation quantity of light corresponding to an applied-voltage value does not almost have quantity of light loss, and can carry out to a high speed arbitrarily.
[0061] Moreover, the optical outgoing radiation edge of the optical fiber by the side of outgoing

radiation is turned to an illuminated object, and the liquid crystal optical equipment of this invention installs it, and when carrying out optical high measurement of a S/N ratio by the lock-in amplifier, it can use the electrical signal of photodetectors, such as the photomultiplier tube and Si photodiode, as a required fiber type light chopper. Compared with a conventional pivoted window type chopper or a conventional oscillatory type chopper, small and high-speed optical chopping becomes possible.
[0062] Moreover, by incorporating with the image storage of image metering devices, such as a CCD camera, making it synchronize with timing, and carrying out the high-speed shutter ring of the liquid crystal optical element, high image measurement of a S/N ratio is attained, in application of obtaining the binarization processing image of the image after image measurement, a shape recognition, etc., it is highly precise, and high-speed processing is attained.
[0063] Moreover, when using the liquid crystal optical equipment of this example as a lighting system, generally a dark part tends to produce the light which outgoing radiation is carried out from a bundle fiber, and is emitted in the shape of a cone in an optical-axis core. This is because the light of the include-angle field of 10-degree or less extent runs short to an optical axis among the light which luminescence of the light source is the effect of the shade produced by the lamp tube wall or the filament, and carries out incidence to an aperture diaphragm. in order to improve such heterogeneity, it is effective to install cone-like prism or a cone-like reflector in an aperture-diaphragm location (the secondary focus of an ellipse mirror prepared in a light source system — for a location to be corresponded to mostly), and to supply light to the include-angle field of 10-degree or less extent to an optical axis. This can attain equalization of the flux of light.
[0064] The configuration of the cone-like prism used here or a cone-like reflector becomes settled to the illuminance homogeneity of the exposure side to need with regards to luminous-intensity-distribution distribution of the light source, an ellipse mirror configuration, the focal distance of a plano-convex lens, its effective diameter, etc. When using cone-like prism, it is the concave cone-like prism whose convex cone object-like prism or vertical angle phi whose vertical angle theta by the side of the optical outgoing radiation is 90 degrees - 175 degrees is 185 degrees - 270 degrees, and, specifically, it is good to use with an aperture diaphragm (for the function that the electrode holder a formal aperture stop or for installation is also almost equivalent to be achieved).
[0065] An unnecessary light is removed by the aperture diaphragm and it is collected into equalization of the flux of light, and the one flux of light by cone-like prism. Since it is desirable to make it the size according to the aperture of the optical fiber for outgoing radiation used, the size of the flux of light is good to prepare the aperture diaphragm of a suitable dimension etc.
[0066] In the optical-communication field etc., when only the total light value of fiber outgoing radiation light is needed and there is no constraint about the luminous-intensity-distribution angular distribution, it is equal, and when the incident light to a liquid crystal optical element is uniform, the orientation distribution of light by which outgoing radiation is carried out from the diameter of the light source does not need to install the component for equalization especially, and is good at an aperture diaphragm or a monotonous reflecting mirror.
[0067] On the contrary, distribution is [ whenever / orientation angle / of fiber outgoing radiation light ] uneven, and when the exposure section serves as ununiformity quantity of light distribution and poses a problem as a lighting system according to it, homogeneity distribution improves by using cone-like prism or a cone-like reflector. In the light source system using the ellipse mirror especially shown in the example as a converging mirror, since it is easy to produce a shadow in a core, cone-like prism or a cone-like reflector is effective. If cone-like prism is used combining an aperture diaphragm, a still better result will be obtained.
[0068] Moreover, when using a cone-like reflector, it is desirable that it is the concave reflector whose convex reflector or vertical angle gamma whose vertical angle beta of a reflector is 150 degrees - 177 degrees is 183 degrees - 210 degrees. Since the effective reflector product of itself achieves the same diaphragm function as an aperture diaphragm, this cone-like reflector is simple.
[0069] Although cone-like prism is not used near the secondary focus location, if this cone-like

prism is further used together in this example When what was about 30% of the maximum illuminance within an exposure side forms the convex cone object-like prism whose vertical angle theta is 120 degrees, the illuminance in the optical-axis core of an optical fiber exposure side The illuminance in the optical-axis core of an exposure side turned into the maximum illuminance, the illumination distribution which carries out gently-sloping reduction was acquired in the radius vector direction, and illuminance homogeneity good as a lighting system with a high-speed modulated light function was acquired.

[0070] Moreover, when a plano-convex lens is used as a condensing means, it is desirable to paste up the convex of a lens with the binder with which air was faced and refractive-index matching was able to take the flat side to the glass substrate side of a liquid crystal optical element. At this time, the curvature part which produces and cheats out of the unnecessary normal reflection which surely carries out incidence to an outgoing radiation side optical fiber in the interface of the convex of a lens and air exists. If a light absorption object is prepared only in a part for this curvature surface part or the detailed irregularity for normal reflective reduction is formed, this interface reflection will be reduced.

[0071] Since the area in which a light absorption object is formed here is minute, the transmissibility of the light as the whole liquid crystal optical equipment is hardly influenced. Moreover, metallic reflection mirrors, such as aluminum, are sufficient as a reflector, and an optical interference multilayers reflecting mirror is sufficient as it. In the case of the former, in order that a reflector may serve also as an electrode, manufacture is easy, and a liquid crystal optical element can be constituted without complicating structure. In the case of the latter, it is also possible to form the cold mirror which has the spectral characteristic which penetrates a heat ray and reflects only the light by the configuration of optical interference multilayers, and it has the degree of freedom which can also form the mirror of 100% of reflection factors to the specific semiconductor laser wavelength used by optical communication.

[0072] By considering as the arrangement configuration of the light source optical system, the condensing means and liquid crystal optical element like this example, and the optical fiber for an output, the transfer loss to the bundle fiber which constitutes an optical fiber decreased, and the higher optical equipment of efficiency for light utilization was obtained. It became possible to use the light source of the large quantity of light especially, and it is low loss and precise optical control was attained.

[0073] In this example, although the bundle fiber was used as an optical fiber, a single fiber with big aperture is sufficient. Since there is no flexibility when the core section with a diameter of about 5mm is formed with glass, the structure which makes a clad air by using plastics and translucency rubber as a core is sufficient. In order to prevent the dirt of an interface with air, it is desirable to apply the fluororesin of a low refractive index to a front face.

[0074] Although photoconductive close effectiveness is bad since the occupancy area of the core part which light actually transmits is as low as 50 - 80% in the case of a bundle fiber, in the case of such a diameter core fiber of single track macrostomia, photoconductive close effectiveness is as high as 90% or more.

[0075] (Example 2) An example 2 is shown in drawing 2 . The liquid crystal optical equipment in this example has the almost same configuration as an example 1. The description here is that some interfaces of a liquid crystal optical element equipped with the function which has a reflective mold mode of operation and modulates light are slanting to an optical axis. Specifically, only whenever [ predetermined tilt-angle / alpha ] is formed [ the liquid crystal solidification object complex layer ] for the inclination to the perpendicular and flat light reflex means 90 to the symmetry axis of incident light and the reflected light.

[0076] The field of transparent two front electrode 30A which consists of ITO of a liquid crystal table optical element etc., and flesh-side electrode 30C is flat. And it is arranged so that the unnecessary reflected light generated from the interface of the liquid crystal solidification object complex layer 30B may carry out incidence to the optical fiber 50 by the side of outgoing radiation, and may not cause degradation of an extinction ratio, and liquid crystal solidification object complex layer 30B may incline to an optical path.

[0077] alpha should just be a value to which the normal reflection by that interface reduces

reaching the optical fiber 50 by the side of outgoing radiation finally whenever [ this tilt-angle ]. What is necessary is just to specifically make the tilt angle alpha of liquid crystal solidification object complex into the big value from the point on the reflector in a light reflex means to the prospective angle when expecting the effective radius (it being the effective radius of the whole bundle fiber in the case of a bundle fiber) of an optical fiber.

[0078] Since the core diameter is as thin as 200 micrometers or less, the range of alpha of 0.1 degrees – 10 degrees is [ whenever / tilt-angle ] desirable in the case of the single track fiber for optical communication. Since it uses as a bundle fiber in the case of the fiber for optical energy transmissions, and the diameter of a fiber of the optical transmission section is as thick as about 2-20mm, 1 degree – about 20 degrees of alpha are [ whenever / tilt-angle ] on the other hand, desirable.

[0079] Furthermore, although the interface reflected light is removed also when it considers as whenever [ big tilt-angle ], the light which carries out incidence from across becomes most at a liquid crystal solidification object complex layer, and effectual permeability falls that it is easy to produce Hayes accompanying index mismatching at the time of transparence. Moreover, since a liquid crystal optical element will become thick and the magnitude and weight of the whole equipment will increase if alpha becomes large whenever [ tilt-angle ], limiting to the above-mentioned range is [ whenever / tilt-angle ] desirable [ alpha ].

[0080] In this example, since the effective radius of the bundle fiber 50 is 2.5 mm and the distance to a reflector 90 is about 50mm, a prospective angle becomes about 3 degrees. Therefore, it is enough if the tilt angle alpha of liquid crystal solidification object complex is made into 5 degrees in this case.

[0081] Light is reflected by the light reflex means 90 formed in the tooth back of a liquid crystal optical element. This is good at the aluminum film or other metal membranes. Or the cold mirror using the optical interference multilayers which reflect the light and penetrate infrared light is sufficient.

[0082] A heat regulator 60 can be formed in the flat side on the background of the light reflex means 90. Or after forming in the side face of prism 80 in which it has a small vertical angle corresponding to alpha whenever [ tilt-angle / to make / of liquid crystal solidification object complex layer 30B and the light reflex means 90 ], as a reflector, the liquid crystal optical element 30 and a heat regulator 60 may be pasted with optical adhesives. In order not to reduce permeability, the adhesion method which used the latter prism 80 is desirable.

[0083] In this example, in order to perform a temperature control to accuracy more and to secure the repeatability of an optical property also to large environmental temperature, the cold mirror was formed as a light reflex means 90, and the heat sink where the Peltier device and temperature sensor of electronics control were embedded as a heat regulator 60 was used.

[0084] When the configuration of an example 2 estimated the optical property, in the large environmental temperature of -20 to 80 degrees C, the property of an extinction ratio 350 was always shown, and the result of having been stabilized by the applied-voltage pair optical output property to the temperature change in coincidence was obtained. Moreover, compared with the aluminum reflecting mirror, since the reflection factor was high about 10%, the direction of a cold mirror of relative light transmittance was a high value compared with the example 1 of a comparison.

[0085] (Example 1 of reference) The example 1 of reference is shown in drawing 3 . In this example, an optical fiber is used for the both sides of I/O of light, and the edge of each optical fiber by the side of incidence and outgoing radiation is arranged near the center of curvature of the condensing means in an optical path. The conventional example (liquid crystal optical equipment which has two optical fibers shown in drawing 7 ) and basic arrangement which mentioned this arrangement above serve as almost same configuration. It is made to stick a plano-convex lens 40 to the side front of the liquid crystal optical element 30 through a glue line.

[0086] In this example 1 of reference, irregularity is prepared in the interface of one electrode 30A of the liquid crystal optical element 30. With this irregularity, unnecessary interface reflection of a liquid crystal optical element is removable. It is prepared almost in parallel by

liquid crystal solidification object complex 30B and un-transparence flesh-side electrode 30C which is a light reflex means.
[0087] Furthermore, in the liquid crystal optical equipment of the example 1 of reference, it has composition which can carry out forcible temperature control of the liquid crystal optical element from a reflector side like examples 1 and 2. As a compulsive temperature control method, it equips with a heat sink and cools with an air cooling fan. Or it can equip with a Peltier device, an electrical heater, and a temperature sensor, and temperature control of heating and the cooling can also be performed and carried out so that it may be maintained by fixed temperature.
[0088] (Example 2 of reference) The example 2 of reference is shown in drawing 4 . Unlike the example 1 of reference, this liquid crystal optical equipment is made into the field where an electrode surface is flat. In this case, it is also possible to paste a reflector, after using not a glass substrate but a PET film with ITO for a substrate and forming a transparency mold component.
[0089] What is necessary is to just be mostly condensed by the location of the optical incidence edge of the optical fiber 52 for outgoing radiation which the light by which an aspheric lens is sufficient as and outgoing radiation was carried out from the optical fiber 51 for one incidence as a plano-convex lens 40 in addition to the spherical lens converges with the plano-convex lens 40 which is a condensing means, and has it in a conjugation-location in these examples of reference. The black coating of the shape of a spot with a diameter of about 1mm was applied to the core of a liquid crystal display component, the light absorption object 70 was established, and reflection of the part was lost so that interface reflection with the liquid crystal optical element 30 and the external worlds (filler gas inside air or a case etc.) might carry out incidence to the optical fiber 52 by the side of outgoing radiation and might not cause degradation of an extinction ratio.
[0090] Moreover, in order to raise permeability, the coat of the antireflection film has been carried out to convex surface 40a of a plano-convex lens 40. Also in these examples of reference, the heat sink was pasted up and the temperature control was performed by the same approach as an example 1.
[0091] When the configuration of the example 1 of reference and the example 2 of reference estimated the optical property, the example 1 and the evaluation result of an extinction ratio good almost similarly were obtained. In the above explanation, although it is pasting up and unifying after separating and producing a liquid crystal optical element and a plano-convex lens, electrodes, such as ITO, are directly formed in the flat side of a plano-convex lens, and it is good also considering itself as a counterelectrode substrate of one of the two of a liquid crystal display component.
[0092] (Example 3 of reference) Although it was the almost same configuration as the example 2 of reference of drawing 4 , the plastics aspheric surface plano-convex lens whose effective diameter the focal distance of the plano-convex lens which is a condensing means using the single track optical fiber for optical-communication information transmissions instead of the bundle fiber for energy transmission about the optical fiber by the side of incidence and outgoing radiation is 20mm, and is 10mm was used. Measuring area of a liquid crystal optical element was made into the larger configuration than the measuring area of a plano-convex lens.
[0093] The single track optical fiber used the compound glass fiber whose core which is the optical transmission section is the diameter of 200 micrometers. Moreover, the black painting of about 0.5 mm was formed in the center section of the convex of a plano-convex lens as a light absorption object. Other configurations presupposed that it is the same as the example 2 of reference. The used light source is semiconductor laser with an oscillation wavelength of 850nm, the dielectric multilayer reflecting mirror whose reflection factor of 850nm is 100% was formed in the reflector upwards, and the ITO film is formed as a transparent electrode.
[0094] As a result of this configuration's estimating an optical property, the property which an extinction ratio calls 5000 and a speed of response always calls 3msec(s) with the large environmental temperature of -20 degrees C - 80 degrees C was shown, and the result of having been stabilized by the applied-voltage pair optical output property to the temperature change in

coincidence was obtained.
[0095] Thus, while there has almost been no optical loss by the configuration of the example of reference, the improvement in fast of an extinction ratio and stability are attained. Therefore, even if it is liquid crystal optical equipment of the example of reference, adjustment of the outgoing radiation quantity of light corresponding to an applied-voltage value can carry out to a high speed arbitrarily [ there is no quantity of light loss and ] by using as a good light variation attenuator for optical communication.
[0096] (Example 3) The block diagram of overall arrangement of an example 3 is shown in drawing 5 . the liquid crystal optical element 30 -- the part -- the expanded sectional view is shown. Although the basic configuration of a light source system was the same as the example 1, 150W and a metal halide lamp with an arc length of 5mm were used as the light source. Moreover, in the opening location of an aperture diaphragm 14, the diameter of 10mm and the cone-like reflector 13 by which the cold mirror was formed by the side face of cone-like prism in which the vertical angle beta was 160 degrees have been arranged, and two bisectrices of a vertical angle leaned 30 degrees of opticals axis, and have arranged. By using such a cone-like reflector 13, the illumination distribution of the incident light to the liquid crystal optical element 30 was equalized.
[0097] The liquid crystal optical element 30 in this example is considered as the electrode configuration which can impress and drive an electrical potential difference for every electrode pair with which it was divided into plurality so that the electrode which counters might become the same configuration, and each was divided. Moreover, a plano-convex lens is arranged by 1 to 1 in the shape of an array, and is made to stick to the front-face side of a liquid crystal optical element through a glue line for every electrode pair. Incidence is carried out to liquid crystal solidification object complex layer 30B by which the light which carried out incidence to the liquid crystal optical element was pinched by each electrode pair through each plano-convex lens from the optical light source system of the same configuration as an example 1.
[0098] It is reflected with the light reflex means (it is made to serve a double purpose for flesh-side electrode itself, or the reflector of dedication is formed in the background) formed in one electrode side (background) of liquid crystal solidification object complex layer 30B, and the reflected light is condensed by different location through the again same liquid crystal solidification object complex layer 30B and each plano-convex lens, and two or more generation of the conjugate image of the aperture diaphragm of the light source system corresponding to the number of plano-convex lenses is carried out. Since this conjugate image dissociates respectively and is formed corresponding to the number of each plano-convex lens, a condensing point is generated only for the number of electrode pairs divided as a result.
[0099] Two or more optical fibers which have an effective diameter corresponding to the magnitude of a conjugate image at the condensing point that two or more of these conjugate images are formed are installed in an optical outgoing radiation side. Therefore, by controlling independently the high-frequency voltage impressed between each electrode pair, the dispersion condition of liquid crystal solidification object complex layer 30B between each electrode pair changes independently respectively, and can control independently the outgoing radiation quantity of light of two or more optical fibers by the side of outgoing radiation.
[0100] In this example, seven-piece (one core, six peripheries) contiguity of the electrode pair of a forward hexagon was carried out, it has been arranged, the electrode substrate which wired so that electrical-potential-difference impression could be carried out independently was prepared, front electrode 30A by the side of optical incidence considered as the frosting side in which the same irregularity as an example 1 was formed, and another flesh-side electrode 30C was taken as the aluminum electrode to serve also as a reflector.
[0101] And carried out impregnation exposure of the ingredient of the same liquid crystal solidification object complex as an example 1, the solidification object was made to harden, and the liquid crystal optical element 30 of a transparency dispersion mold was formed. Furthermore, the array of a plano-convex lens with a focal distance of 80mm was pasted up on each electrode pair with the forward hexagon corresponding to the configuration, and black painting with a diameter of about 2mm was given to the core of the convex of a lens as a light absorption object

70.
[0102] The top view which saw from the top the component with which the array of a liquid crystal optical element and a plano-convex lens was united is shown in drawing 6 . a part of liquid crystal optical element 30 shown in drawing 5 -- an expanded sectional view corresponds to the cutting plane of A-A'. In addition, the heat regulator 60 was considered as the same configuration as an example 1.
[0103] The distance of the cone-like reflector 13 of a light source system and the liquid crystal optical element 30 was taken about 120mm, and it has arranged so that about 10 degrees of opticals axis of the light which carries out incidence to the liquid crystal optical element 30 may incline. When the liquid crystal optical element 30 was transparence, the conjugate image of a cone-like reflector side was formed in the liquid crystal optical element and the location distant 60mm as a round shape of seven about 5mm diameters of the array of a plano-convex lens with a focal distance of 80mm, and the reflector of a liquid crystal optical element. A total of seven optical fibers with a diameter of 6mm was installed in each conjugate-image location.
[0104] The optical fiber used here used as the core of a 6.5 mm diameter the object into which the elastomer made from translucency silicone resin was processed in the shape of a rod, and what covered the fluororesin of a low refractive index as a clad on the periphery was used for it. Since an optical transmission loss becomes large compared with the bundle fiber which bundled and used the textile-glass-yarn optical fiber by using such a single track optical fiber, it is not suitable for long-distance transmission, but since core area can take greatly, and photoconductive close effectiveness is high, in the optical energy transmission which is 10m or less extent, low cost-ization of the whole transmission efficiency is attained highly.
[0105] While dividing the outgoing radiation light from the single light source into plurality efficiently and being able to carry out the light guide with the optical fiber by using the liquid crystal optical equipment of this example, the light of the quantity of light of the light by which a light guide is carried out with each optical fiber was able to be independently stabilized and modulated at the high speed. Therefore, if the liquid crystal optical equipment of this example is carried in an automobile, from the single light source, two or more optical fibers can divide, a light guide can be carried out, and it can use as a head lamp, a tail lamp, a tonneau light, and the light source for instrument panels. Moreover, it has a function suitable for the dynamic production of stage lighting or inside-of-a-shop lighting.
[0106] In the liquid crystal optical equipment of this example, modulated light of each colored light or modulated light of the color of arbitration is attained by combining the light from the single light source with color separation or the function which carries out color composition using a dichroic mirror.
[0107] Moreover, constitutionally, since [ of this invention ] a heat regulator can be installed in one side of a liquid crystal optical element, by compulsory temperature control, it can maintain now at the temperature by which the optimal characteristics of a liquid crystal optical element are always discovered regardless of the quantity of light and the wavelength band which are used, or perimeter environmental temperature, and the stable modulated light or the stable optical shutter ring is obtained.
[0108] As mentioned above, although the example was explained, an approximate account is performed about the magnitude of each part etc. next. In transmitting light energy, a halogen lamp, a metal halide lamp, Xe lamp, etc. are used as the light source, and in order for all to condense efficiently using a condensing means and for luminescence length to do a light guide to a fiber about 2-10mm for a certain reason, the fiber diameter of about 3-10mm is needed.
[0109] Moreover, the magnitude of the light source has the width of face of 10-30cm (500W-3kW) extent from die length of 3-10cm (10W - 500W class), and the magnitude of a converging mirror will also be doubled according to the classification of the light source. Although the magnitude of a liquid crystal optical element is decided according to N.A. of the magnitude, for example, the focal distance and effective diameter, and the fibers of the condensing means to be used (an ellipse mirror, lens, etc.) etc., when using the above-mentioned light source, the thing of about 1-30cm of vertical angles is about used for it. In this invention, a high property can be attained irrespective of the magnitude of a liquid crystal panel.

[0110] In using for the purposes, such as a communication link and optical measurement, the incidence aperture of light is 1mm or less, and the diameter is set to 1cm or less even if it uses a lens, since the emission light of laser die auto or LED is condensed. Since the optical transmission section core diameter of the single track fiber for optical communication is 200-micrometer or less extent, the magnitude of a liquid crystal optical element is set to about about 1-5cm. Since semiconductor laser light etc. is used, light serves as almost single wavelength. Even in this case, the actuation by which the quantity of light was relatively stabilized with precise control as it is small is guaranteed.
[0111] (Example 4 of reference) The example 4 of reference is shown in drawing 8 . It is what improved further the example equipped with alpha whenever [ tilt-angle / which was mentioned above ], and is the example which gave whenever [ tilt-angle ] to the liquid crystal optical element using two wedge-shaped prism objects, and made parallel mostly the reflector and the flat side of a plano-convex lens. The property equivalent to the example mentioned above was acquired.

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[Translation done.]

## DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] The block diagram which drew typically overall arrangement of an example 1 (example equipped with an ellipse mirror, the aperture diaphragm, the light absorption object, the front electrode of a concave convex, and the optical fiber by the side of outgoing radiation).
[Drawing 2] The block diagram of an example 2 (example equipped with alpha whenever [ light absorption object and tilt-angle ]).
[Drawing 3] The block diagram of the example 1 (example equipped with the light absorption object and the front electrode of a concave convex) of reference.
[Drawing 4] The block diagram of the example 2 (example equipped with alpha whenever [ light absorption object and tilt-angle ]) of reference.
[Drawing 5] The block diagram showing the overall arrangement configuration of an example 3 (example equipped with the front electrode of an ellipse mirror, an aperture diaphragm, a cone-like reflector, a plano-convex lens array, and a concave convex etc.).
[Drawing 6] The top view of a liquid crystal optical element used for an example 3.
[Drawing 7] The block diagram of the conventional example.
[Drawing 8] The block diagram of the example 4 (example which gave whenever [ tilt-angle ] to the liquid crystal optical element using two prism objects, and made parallel mostly the reflector and the flat side of a plano-convex lens) of reference.
[Description of Notations]
1: Liquid crystal optical equipment
11: Light source
12: Ellipse mirror
13: Cone-like prism or a cone-like reflector
14: Aperture diaphragm
30: Liquid crystal optical element
30A: Front electrode
30B: Liquid crystal solidification object complex layer
30C: Flesh-side electrode (a transparent electrode or un-transparence aluminum electrode)
40: Plano-convex lens
50: Optical fiber
60: Heat regulator
70: Light absorption object

[Translation done.]

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DRAWINGS

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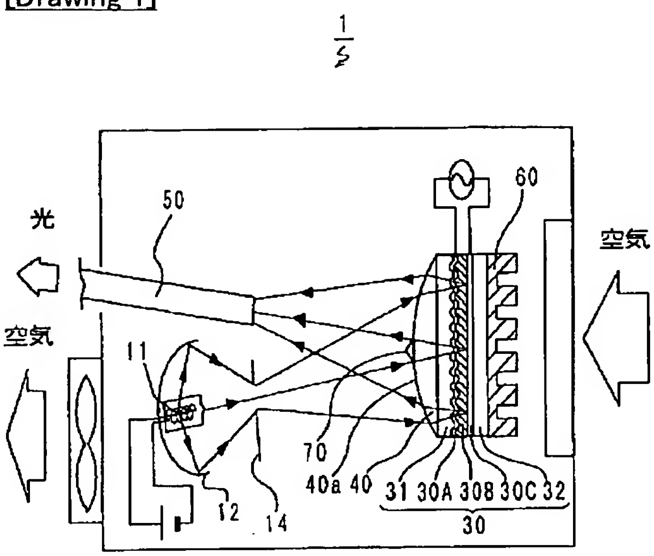
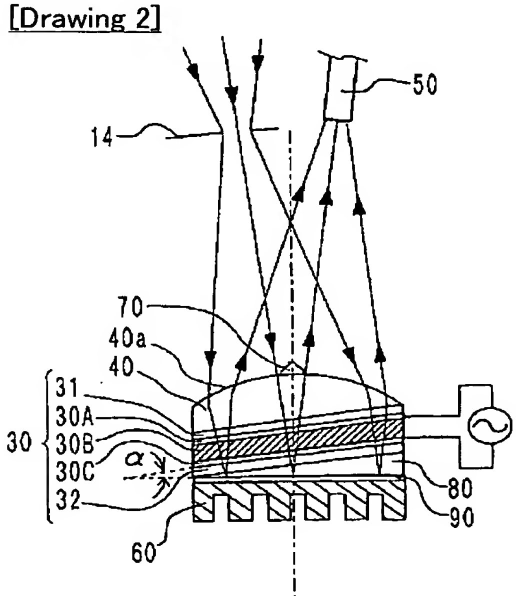
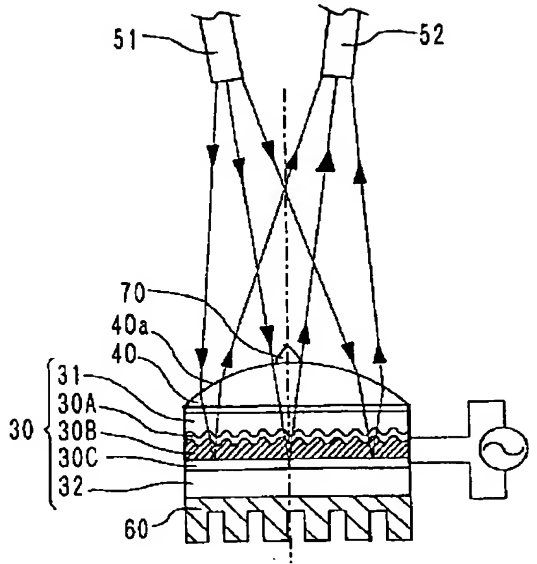
[Drawing 1]



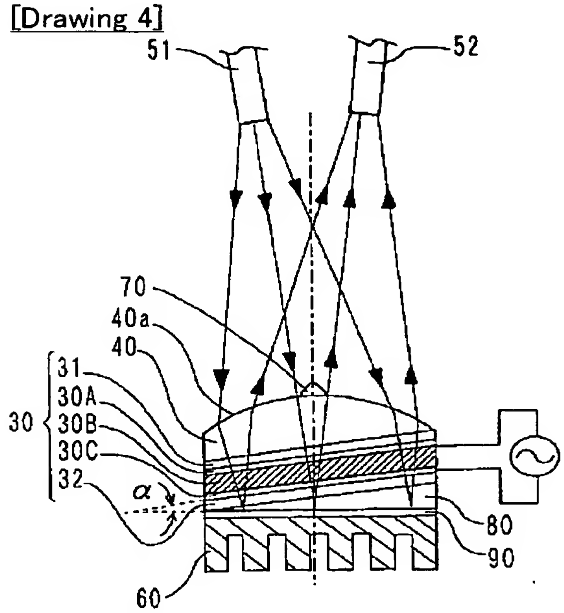

[Drawing 2]



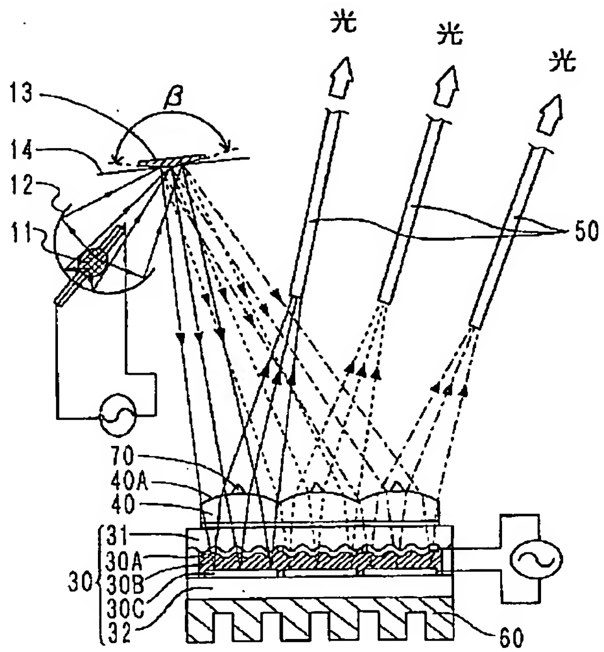

[Drawing 3]



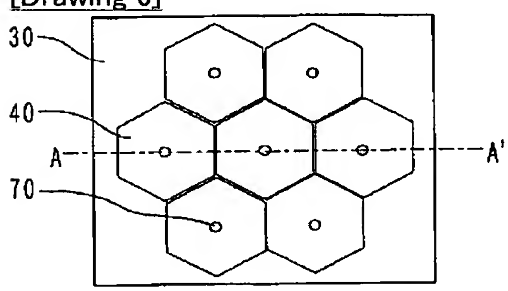

[Drawing 4]



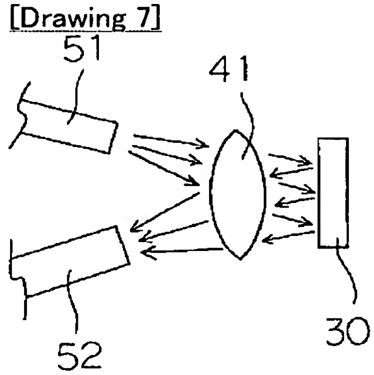

[Drawing 5]



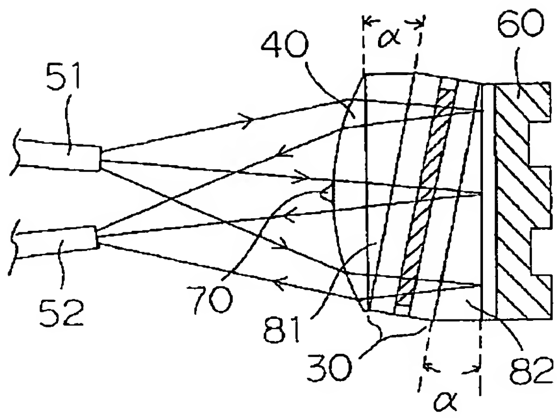

[Drawing 6]




[Drawing 7]




[Drawing 8]




[Translation done.]

(19)日本国特許庁（ＪＰ）　(12) 公開特許公報（Ａ）　(11)特許出願公開番号

特開平6－281909

(43)公開日　平成６年(1994)10月７日

| (51)Int.Cl.⁵ | | 識別記号 | 庁内整理番号 | F I | 技術表示箇所 |
|---|---|---|---|---|---|
| Ｇ０２Ｆ | 1/13 | ５０５ | 9119－2K | | |
| | 1/1333 | | 9317－2K | | |
| | 1/1335 | | 9017－2K | | |

審査請求　未請求　請求項の数10　ＦＤ　（全 13 頁）

(21)出願番号　特願平5－92300

(22)出願日　平成５年(1993)３月26日

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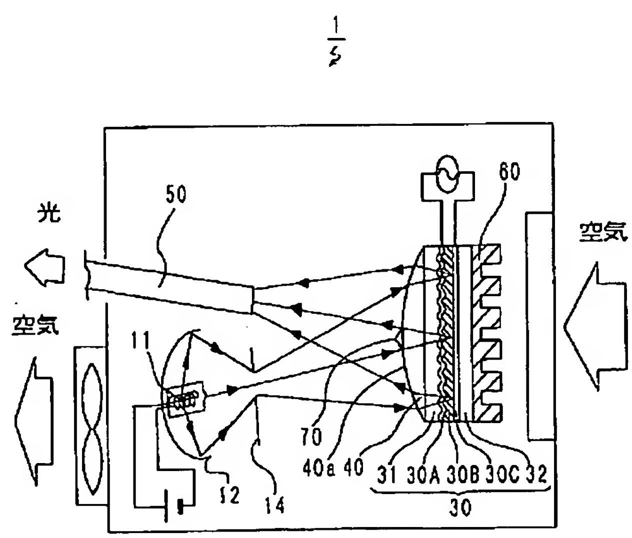
(54)【発明の名称】　液晶光学装置及びそれを用いた照明装置

(57)【要約】

【構成】楕円鏡１２と光源１１と開口絞り１４と、表電極３０Ａ、光が２回通過せしめられる液晶固化物複合体層３０Ｂ、裏電極３０Ｃを備えた液晶光学素子３０と、平凸レンズ４０と光ファイバ５０とが設けられ、光路中の界面が凹凸面とされるか、もしくは傾斜角度$\alpha$を有するかされ、または平凸レンズ表面４０ａに光吸収体７０が設けられて不要な正規反射光が低減され、変調光が光ファイバ５０に出射される液晶光学装置１。

【目的】高性能の光変調器を得る。



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【特許請求の範囲】

【請求項１】光源と、
集光手段と、
それぞれ電極付の一対の基板間に、液晶が固化物マトリックス中に分散保持された液晶固化物複合体が挟持され、電極間に発生する電界によって液晶が制御され、液晶の屈折率が固化物マトリックスの屈折率に一致しない際に光が散乱し、液晶の屈折率が固化物マトリックスの屈折率とほぼ一致した際に光が透過する液晶固化物複合体層を備えた液晶光学素子と、
光反射手段と、
光ファイバとが設けられ、
光源から光ファイバに至る光路の途中に光反射手段が光路を折り曲げるように設けられ、
液晶光学素子は光反射手段の反射面側に配置され、
光源から出射された光は集光手段を通過せしめられ、さらに液晶光学素子の第１の面から入射され液晶固化物複合体層を通過せしめられ、さらに光反射手段に至り、光反射手段で反射され液晶固化物複合体層を通過せしめられ、液晶光学素子の前記第１の面から出射され、集光手段を通過せしめられ、光ファイバの光入力端にほぼ集光され、
液晶光学素子での光の透過と散乱によって光源から光ファイバに伝達される光量が制御される液晶光学装置において、
光反射手段は液晶固化物複合体層に近接または密着され、集光手段は平凸レンズからなり、該平凸レンズは液晶光学素子の前記第１の面に接して設けられ、
光源から光ファイバに至るまでの光路中に存在する界面のうち少なくとも１つの界面に凹凸が設けられるか、
少なくとも１つの界面が光反射手段に対して所定の傾斜角度αだけ傾斜せしめられたことを特徴とする液晶光学装置。

【請求項２】請求項１の界面に凹凸が設けられた液晶光学装置において、液晶光学素子の少なくとも一方の電極面に凹凸が形成されたことを特徴とする液晶光学装置。

【請求項３】請求項１の傾斜角度αだけ傾斜せしめられた液晶光学装置において、傾斜角度αは光反射手段における反射面上の点から光ファイバの有効半径を見込んだときの見込み角よりも大きな値とすることを特徴とする液晶光学装置。

【請求項４】請求項１～３のいずれか１項の液晶光学装置において、平凸レンズの凸面上の一部に光吸収体または散乱体が設けられたことを特徴とする液晶光学装置。

【請求項５】請求項１～４のいずれか１項の液晶光学装置において、液晶光学素子の光反射手段が設けられた基板側に、さらに温度調整器が設けられたことを特徴とする液晶光学装置。

【請求項６】請求項１～５のいずれか１項の液晶光学装置において、光源から液晶光学素子への導光手段として

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楕円鏡がさらに設けられてなることを特徴とする液晶光学装置。

【請求項７】請求項６の液晶光学装置において、
楕円鏡の第一焦点近傍に光源が配置され、
楕円鏡の第二焦点近傍に集光均一化手段として錐体状プリズムと開口絞りが組合わされて配置されるか、または錐体状反射体が配置され、
光源からの出射光は楕円鏡で第二焦点近傍に集光され、さらに、前記集光均一化手段によって集束され均一化された光束が液晶光学素子へ入射せしめられることを特徴とする液晶光学装置。

【請求項８】請求項７の液晶光学装置において、錐体状プリズムの光出射側の頂角θが９０°～１７５°である凸錐体状プリズム、もしくは頂角φが１８５°～２７０°である凸錐体状プリズムとされたことを特徴とする液晶光学装置。

【請求項９】請求項７の液晶光学装置において、錐体状反射体の反射面の頂角βが１５０°～１７７°である凸反射体、もしくは頂角γが１８３°～２１０°である凹反射体とされたことを特徴とする液晶光学装置。

【請求項１０】請求項１～９のいずれか１項の液晶光学装置を備えた照明装置。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は、光ファイバと液晶固化物複合体を備えた透過散乱型の液晶光学素子とを用いた液晶光学装置、及びそれを用いた照明装置に関する。

【０００２】

【従来の技術】従来から光源と光伝送用の光ファイバとの間に液晶光学素子を配置して、液晶光学素子により光源から光ファイバに伝達される光量を制御する液晶光学装置が知られている。さらに、光エネルギー伝送用の光ファイバ、または単線の光ファイバを束ねたバンドルファイバと光源と液晶光学素子とを用いた照明装置や配光装置が提案されている。

【０００３】また、光源から液晶光学素子への導光手段に光ファイバを用い、光ファイバと光ファイバとの間に液晶光学素子を配置した構成が提案されている。図７に従来例としてその基本配置を示す。入射用の光ファイバ５１と出射用の光ファイバ５２と凸レンズ４１と反射モードの液晶光学素子３０とが空間的に離れて配置されている。さらに、液晶光学素子３０はその内部に液晶固化物複合体層を電気光学的な機能層として有し、透過散乱型の動作モードを示す。そして、この構成により光の変調を達成する。

【０００４】また、この従来例と似たような配置構成であるが、光通信情報伝送用の低損失細線光ファイバを液晶光学素子の光入射側及び光出射側に用いた光可変減衰器が提案されている。以上のように、透過散乱型の動作モードを有し偏光板なしで光の制御を行うことのできる

液晶固化物複合体を備えた液晶光学素子を用いることにより光損失の低減が可能となることから、反射型液晶光学素子とレンズを用いても光可変減衰器が構築可能であることが提案されている。

【0005】

【発明が解決しようとする課題】この場合、反射型の構成とすることによって液晶固化物複合体層を光が２回通過するため、液晶固化物複合体自体の散乱能は１回のみ光が通過する透過型の構成に比べ飛躍的に向上する。

【０００６】しかし、液晶光学素子の界面及び集光用レンズの界面などにおいて生じる界面反射の一部が光出射側の光ファイバに常時入射するため、液晶固化物複合体が散乱状態のとき、光ファイバからの出射光量は低くならず、液晶固化物複合体層への電圧印加及び非印加による出射光の消光比は透過型の構成に比べ高いとはいえなかった。

【０００７】したがって、液晶光学素子の電圧印加に伴う光量変化のダイナミックレンジは透過型の素子構成に比較して改善されることはほとんどなく低い特性値のままであった。また、多量の光を放出する光源を用いた場合、放射熱などに伴う液晶光学素子の温度上昇は著しく、各種の電気光学特性（印加電圧対光透過率の特性、ダイナミック応答特性、消光比等）の再現性が低くなり正確な調光ができなかった。

【０００８】また、光源からの出射光を楕円鏡で集光し、最終的に光ファイバから出射光を得る照明装置の場合、照射面の中央部に照度の低い領域が生じ、均一照明装置として問題となっていた。例えば、電子部品が実装された回路基板に光ファイバからの出射光を照射し、その画像をＣＣＤカメラで入力してから二値化画像処理を行い実装の良否を判定する検査装置等に置いて、照射光の面内均一性が劣ると判定精度が低下するため問題となっていた。

【０００９】

【課題を解決するための手段】本発明は、光源と、集光手段と、それぞれ電極付の一対の基板間に、液晶が固化物マトリックス中に分散保持された液晶固化物複合体が挟持され、電極間に発生する電界によって液晶が制御され、液晶の屈折率が固化物マトリックスの屈折率に一致しない際に光が散乱し、液晶の屈折率が固化物マトリックスの屈折率とほぼ一致した際に光が透過する液晶固化物複合体層を備えた液晶光学素子と、光反射手段と、光ファイバとが設けられ、光源から光ファイバに至る光路の途中に光反射手段が光路を折り曲げるように設けられ、液晶光学素子は光反射手段の反射面側に配置され、光源から出射された光は集光手段を通過せしめられ、さらに液晶光学素子の第１の面から入射され液晶固化物複合体層を通過せしめられ、さらに光反射手段に至り、光反射手段で反射され液晶固化物複合体層を通過せしめられ、液晶光学素子の前記第１の面から出射され、集光手段を通過せしめられ、光ファイバの光入力端にほぼ集光され、液晶光学素子での光の透過と散乱によって光源から光ファイバに伝達される光量が制御される液晶光学装置において、光反射手段は液晶固化物複合体層に近接または密着され、集光手段は平凸レンズからなり、該平凸レンズは液晶光学素子の前記第１の面に接して設けられ、光源から光ファイバに至るまでの光路中に存在する界面のうち少なくとも１つの界面に凹凸が設けられるか、少なくとも１つの界面が光反射手段に対して所定の傾斜角度αだけ傾斜せしめられたことを特徴とする液晶光学装置（１）を提供する。

【００１０】また、この界面に凹凸が設けられた液晶光学装置（１）において、液晶光学素子の少なくとも一方の電極面に凹凸が形成されたことを特徴とする液晶光学装置（２）を提供する。また、この傾斜角度αだけ傾斜せしめられた液晶光学装置（１）において、傾斜角度αは光反射手段における反射面上の点から光ファイバの有効半径を見込んだときの見込み角よりも大きな値とすることを特徴とする液晶光学装置（３）を提供する。

【００１１】また、上記の液晶光学装置（１）～（３）のいずれか１つにおいて、平凸レンズの凸面上の一部に光吸収体または散乱体が設けられたことを特徴とする液晶光学装置（４）を提供する。

【００１２】また、上記の液晶光学装置（１）～（４）のいずれか１つにおいて、液晶光学素子の光反射手段が設けられた基板側に、さらに温度調整器が設けられたことを特徴とする液晶光学装置（５）を提供する。

【００１３】また、上記の液晶光学装置（１）～（５）のいずれか１つにおいて、光源から液晶光学素子への導光手段として楕円鏡がさらに設けられてなることを特徴とする液晶光学装置（６）を提供する。

【００１４】また、上記の液晶光学装置（６）において、楕円鏡の第一焦点近傍に光源が配置され、楕円鏡の第二焦点近傍に集光均一化手段として錐体状プリズムと開口絞りが組合わされて配置されるか、または錐体状反射体が配置され、光源からの出射光は楕円鏡で第二焦点近傍に集光され、さらに、前記集光均一化手段によって集束され均一化された光束が液晶光学素子へ入射せしめられることを特徴とする液晶光学装置（７）を提供する。

【００１５】また、上記の液晶光学装置（７）において、錐体状プリズムの光出射側の頂角$\theta$が９０°～１７５°である凸錐体状プリズム、もしくは頂角$\phi$が１８５°～２７０°である凸錐体状プリズムとされたことを特徴とする液晶光学装置（８）を提供する。

【００１６】また、上記の液晶光学装置（７）において、錐体状反射体の反射面の頂角$\beta$が１５０°～１７７°である凸反射体、もしくは頂角$\gamma$が１８３°～２１０°である凹反射体とされたことを特徴とする液晶光学装置（９）を提供する。

【００１７】さらに、上記の液晶光学装置（１）～（９）のいずれか１つを備えた照明装置を提供する。

【００１８】本発明の液晶光学装置において、具体的には不要な正規反射光低減手段として液晶光学素子の少なくとも一方の透明な電極面に微細な凹凸が形成されるか、液晶光学素子の液晶固化物複合体層を光反射手段に対して傾斜せしめて設けることで、液晶固化物複合体層と透明な電極付き基板ガラスとの界面などにおいて生じる不要な正規反射光が低減される。

【００１９】また、集光手段と液晶光学素子との間の界面による不要な正規反射光を積極的に抑制するように、一体的な構造を採用し、コンパクトかつ機械的に強固であり光学的に優れた液晶光学装置及び照明装置を提供する。

【００２０】また、本発明の液晶光学装置において、光源から液晶光学素子への導光手段として楕円鏡をまず採用し、さらに集光均一化手段を設ける。楕円鏡の第一焦点近傍に光源を配置し、第二焦点近傍の位置に開口絞りと錐体状プリズム、または錐体状反射体が配置される。ここで開口絞りとは完全なアパーチャストップ以外に同等の機能を達成するものでよい。簡単には、錐体状プリズムのホルダーも開口絞りとして機能する。さらには、黒塗りされたり、つや消しされれば効果的である。好ましくは、正式なアパーチャストップを用いるのがよい。

【００２１】この構成によって、光源からの出射光は楕円鏡で第二焦点近傍の位置に集光され、集光均一化手段でほぼ一つの光束として均一化された光が液晶光学素子へ入射される。この場合、導光手段の構成要素である集光均一化手段として、錐体状プリズム及び開口絞り、または錐体状反射体を用いることにより、光ファイバから出射される光の配光分布を均一化することが可能である。そして、例えば光エネルギー伝送（照明装置）用光ファイバシャッターを提供する。

【００２２】

【作用】本発明によれば、光源から出射された強い光束や、太い光束、あるいは単一波長の光束も精密に導光して、光ファイバに伝達せしめる。このとき、光は液晶固化物複合体層を２回通過するため、透過散乱型光学素子の実効的散乱能が向上する。そして、不要な正規反射光成分を積極的に低減せしめることで、ノイズ成分を大きく低減せしめ強度の強い光をも低損失で正確に伝達する。その結果、従来例に見られたような消光比及びダイナミックレンジの劣化が改善され、強度の強い光の伝達制御が可能となる。

【００２３】また、液晶光学素子の裏面に温度調整器が設けられた場合には、光の液晶光学素子への入射から出射に至るまでの光路上でその光に直接影響を与えることなく、液晶光学素子を強制的に温度制御することが可能となり、液晶光学素子の電気光学特性がきわめて安定する。さらに、強度の強い光の精密な伝達制御を達成することができる。以下、実施例により、本発明を具体的に説明する。

【００２４】

【実施例】

（実施例１）本発明の実施例１を図１に示す。本発明の液晶光学装置は、光源光学系として楕円鏡１２と光源１１と開口絞り１４が用いられる。本実施例では光源１１は楕円鏡１２の第１焦点のほぼ近傍の位置に設けられ、開口絞り１４は楕円鏡１２の第２焦点のほぼ近傍の位置に設けられている。光源１１としてハロゲンランプを用いている。ここで、第１焦点の位置にハロゲンランプのフィラメント部分を設置し、第２焦点の近傍に円形の開口絞り１４が設置されている。もちろん、フィラメント部分の発光部は空間的にある体積があり、完全な点光源ではない。

【００２５】光を出力する光ファイバ５０が配置され、光変調を実行する反射型動作モードを有する液晶光学素子３０、液晶光学素子３０の表側であり光の入出射面となる第１の面に接して平凸レンズ４０が設けられ、液晶光学素子３０の裏側に、その第２の面に接して温度調整器６０が設けられ、さらに液晶光学素子３０を駆動する駆動回路（図示を省略している）、及び温度調整器６０を駆動制御する電気回路などからなる。

【００２６】この温度調整器６０は、基板３２の裏側に位置し、温度センサーと電熱ヒータが内蔵された放熱板を接着したものである。さらに、この温度調整器６０の背後に空冷用ファンを取付け、液晶光学素子３０が設定温度に維持されるように温度をモニターしながら電熱ヒータと空冷用ファンにより温度調整できるようにした。これらの各構成部分は筐体に納められ、一定のエアーフローによる空調によって冷却される。

【００２７】光出射側の光ファイバ５０は、多成分系ガラスを直径５０$\mu$ｍのコアとする開口数（Ｎ．Ａ．）０．５７のファイバを束ねて直径５mmのバンドルファイバとしたものを用いた。各々液晶光学素子３０の液晶固化物複合体層３０Ｂに対して入射角８度で光が入射するよう、主要な正規反射光が到達する位置に配置し、円形の開口絞り１４と光ファイバ５０（バンドルファイバ）の端面の中心とは平凸レンズの焦点位置の近傍で各々光学的に互いに共役な位置関係に設置されている。

【００２８】平凸レンズ４０はその焦点距離が５０mmであり、光学接着剤（図示を省略している）で液晶光学素子３０の第１の面（表側）に接着した。また、平凸レンズ４０の凸表面４０ａには反射防止膜をコートし、さらにその中心部に直径約５mmのスポット状の形に黒色塗料を塗って光吸収体７０を形成し、その部分の反射をなくした。

【００２９】黒色塗料の形成位置及び面積は用いる光ファイバ５０の有効径、レンズの凸面形状に関係して適切な値が存在する。レンズの凸面での反射光が出射側の光

ファイバに入射するような、レンズ凸表面４０ａの正規反射位置に形成することが好ましい。本実施例ではレンズの凸表面４０ａの一部に黒色塗料を塗布して光吸収体７０を形成して不要な界面反射成分を減らしているが、その代わりに同じ領域に凹凸を形成して散乱体を設けて不要な正規反射を低減してもよい。

【００３０】楕円鏡１２の反射面はコールドミラーとした。楕円鏡１２の第２焦点近傍に設置された開口絞り１４の直径は、バンドルファイバである光ファイバ５０の有効径に対応した共役像が液晶光学素子３０の反射性の裏電極３０Ｃと平凸レンズ４０によって結像される位置において、その共役像と同程度の形状としている。

【００３１】具体的には、本実施例では等倍率で共役像を形成しているため、開口絞り１４として出射側バンドルファイバと同じ直径５ｍｍの開口を設置した。また、ランプ発光中に含まれる紫外線及び熱線が液晶光学素子に入射しないように、紫外線及び熱線を吸収もしくは反射する分光特性を有するガラスフィルタをこの開口部に設置した。

【００３２】光源１１から出射された光は楕円鏡１２により集光されて開口絞り１４を通過した光のみが平凸レンズ４０に進む。平凸レンズ４０の凸表面４０ａから入射し、屈折せしめられ液晶光学素子３０に進む。さらに、液晶光学素子３０に入射し、その中の表電極３０Ａ、液晶固化物複合体層３０Ｂを通過し、残る一方の電極でもあり光反射手段でもある非透明な裏電極３０Ｃに当たり、ここで反射する。

【００３３】そして、再び液晶固化物複合体層３０Ｂ、表電極３０Ａを通過し、さらに平凸レンズ４０を通過し、その凸表面４０ａから出射し、屈折して光ファイバ５０のの光入射端に進む。そして、この光入射端の位置でほぼ集束され光ファイバ５０に入射される。つぎに、本発明で用いられる液晶固化物複合体の構成について概説する。

【００３４】本発明における液晶光学素子では、ネマチック液晶が固化物マトリックス中に分散保持された液晶固化物複合体を挟持した液晶表示素子を用いる。特に、正の誘電異方性を有するネマチック液晶が固化物マトリックス中に分散保持され、その固化物マトリックスの屈折率が使用する液晶の常光屈折率（$n_o$）とほぼ一致するようにされた液晶固化物複合体を用いることが好ましい。そして、液晶固化物複合体を、一対の電極付きの基板間に挟持する。

【００３５】ネマチック液晶の$n_o$と異常光屈折率（$n_e$）との差である屈折率異方性を△ｎとすると、△ｎは０．１８以上であることが好ましい。また、特定波長λ（μｍ）に対して液晶固化物複合体層の高い散乱能を得るためには、液晶の平均粒子径Ｒ（μｍ）がその波長に応じて揃っていることが好ましい。実際には、△ｎ・Ｒ≒λの関係を満たすことが好ましい。

【００３６】したがって、光エネルギー伝送用のバンドルファイバを用いて可視光の波長帯域（λ＝０．４～０．７（μｍ））の光を変調する場合、全波長域で液晶固化物複合体層での散乱能がほぼ均一になるためには、液晶の平均粒子径Ｒが、

０．４＜△ｎ・Ｒ＜０．７

の関係を満たす範囲に分布していることが好ましい。

【００３７】一方、光通信用単線ファイバを用い、光として非可視光域の半導体レーザダイオードやＬＥＤの近赤外波長域（λ＝０．８～１．６（μｍ））の単一波長の光を用いる場合、または可視光発振のレーザであるＨｅ－Ｎｅレーザや半導体レーザの単一波長の光を光計測用に用いる場合、液晶の平均粒子径Ｒは、△ｎ・Ｒ≒λを満たすような粒径分布の少ない構造が好ましい。

【００３８】この電極付の基板はガラス、プラスチック、セラミック等の基板上に電極が設けられたものが使用される。基板は形状が固定されたものでもよいし、プラスチックフィルムのように可とう性の基板であってもよい。また、紫外線吸収や赤外線吸収あるいは不要な波長成分を吸収または反射する分光特性を有する基板でもよい。

【００３９】本発明では少なくとも入射面側の基板には透明な材料を用いる。さらに平坦で光学的な歪の少ない基板面を形成するにはガラスが適している。

【００４０】それぞれ電極付の一対の基板間に、液晶固化物複合体を挟持する。この液晶固化物複合体は、電圧の印加により電界が発生し、その電界に応じて液晶分子の配向が変わり、液晶固化物複合体中の液晶の屈折率が変化する。その固化物マトリックスの屈折率が、液晶の屈折率とほぼ一致したときに光が透過し、一致しないときに光が散乱する。この液晶固化物複合体を用いた液晶光学素子は偏光板を用いていないので、光損失の少ない光変調器が得られる。

【００４１】具体的には、液晶表示素子として細かな孔の多数形成された固化物マトリックスとその孔の部分に充填されたネマチック液晶とからなる液晶固化物複合体を用いる。この液晶固化物複合体を、電極基板間に挟持する。その電極間への電圧の印加状態により、その液晶の屈折率が変化し、固化物マトリックスの屈折率と液晶の屈折率との関係が変化する。これら両者の屈折率がほぼ一致したときには透過状態となり、屈折率が異なったときには散乱状態となるような液晶光学素子が使用できる。

【００４２】この細かな孔の多数形成された固化物マトリックスとその孔の部分に充填された液晶とからなる液晶固化物複合体は、マイクロカプセルのような液泡内に液晶が封じ込められたような構造である。しかし、個々のマイクロカプセルが完全に独立していなくてもよく、多孔質体のように個々の液晶の液泡が細隙を介して連通していてもよい。さらに、連通の度合いが高く、液晶が

編み目状に連通している状態でもよい。

【００４３】本発明に用いる液晶固化物複合体は、例えば以下のようにして製造される。ネマチック液晶と、固化物マトリックスを構成する硬化性化合物とを混ぜ合わせて溶液状またはラテックス状にする。次いで、これを光硬化、熱硬化、溶媒除去による硬化、反応硬化等させて固化物マトリックスを分離し、固化物マトリックス中にネマチック液晶が分散した状態をとるようにすればよい。

【００４４】使用する硬化性化合物を、光硬化または熱硬化タイプにすることにより、密閉系内で硬化できるため好ましい。特に、光硬化タイプの硬化性化合物を用いると、熱による影響を受けなく、短時間で硬化させることができ好ましい。

【００４５】具体的な製法としては、従来の通常のネマチック液晶と同様にシール材を用いてセルを形成し、注入口からネマチック液晶と硬化性化合物との未硬化の混合物を注入し、注入口を封止した後、光照射をするか加熱して硬化させることもできる。

【００４６】また、本発明における液晶光学素子の場合には、シール材を用いなく、例えば、対向電極としての反射電極を設けた基板上に、ネマチック液晶と硬化性化合物との未硬化の混合物を供給し、その後、もう一方の透明電極を設けた基板を重ねて、光照射等により硬化させることもできる。

【００４７】もちろん、その後、周辺にシール材を塗布して周辺をシールしてもよい。この製法によれば、単にネマチック液晶と硬化性化合物との未硬化の混合物をロールコート、スピンコート、印刷、ディスペンサによる塗布等の供給をすればよいため、注入工程が簡便であり、生産性が極めてよい。

【００４８】また、これらのネマチック液晶と硬化性化合物との未硬化の混合物には、基板間隙制御用のセラミック粒子、プラスチック粒子、ガラス繊維等のスペーサ、顔料、色素、粘度調整剤、その他本発明の性能に悪影響を与えない添加剤を添加してもよい。

【００４９】以上、光重合法による製造方法を示したが、この他にエマルジョン法によってもマイクロカプセル化液晶を形成できる。また、マイクロポーラスガラスを用い、液晶材料をほぼ均一なガラス孔からカプセル包疲体材料の液体中に圧出することでカプセル粒子径のほぼ揃った液晶固化物複合体を形成することもできる。

【００５０】つぎに、液晶光学素子３０の内部構造について説明する。第１の面（光入出射面）側に位置する表電極３０ＡはＩＴＯなどの透明電極からなっている。そして、表側基板でありガラス製の基板３１のＩＴＯ界面は予めフロスト処理されている。フロスト処理によって形成された凹凸は、その界面での正規反射が最終的に出射側の光ファイバ５０に到達するのを低減する形状であればよい。したがって、反射面３０Ｃと平行な面が多く存在する矩形状の凹凸は不適切であり、傾斜角を有する斜面の集合体である△（鋸歯状）の凹凸が好ましい。

【００５１】この傾斜角は、開口絞り１４及び光ファイバ５０の有効径、反射面である裏電極３０Ｃへの光入射角等に関係するが、一般に傾斜角は垂直に近いほど、即ち鋭い△状の凹凸程不要な界面反射は取り除かれる。しかし、鋭角な程表面積が増大するため、界面反射の割合が増大し、利用できる透過光が減少する。したがって、透過率の著しい低下を招かず、不要な界面反射を低減できる傾斜成分の多い△状の凹凸が好ましい。

【００５２】また、本液晶光学装置は、表示素子のように面内特性の均一性が必要でないため、凹凸の大きさ（ピッチ）に関しての制約は厳しくないが、印加電圧に対する透過光量の特性において、オン－オフ動作の場合のように、より鋭い立ち上がりが必要とされる場合は、凹凸の大きさ（ピッチ）は小さいほど好ましい。一方、中間光量を細かく制御したい調光器等の応用にはなだらかな印加電圧に対する透過光量の特性が必要なため、凹凸のピッチ即ち深さを大きな値とし液晶固化物複合体層の厚みが分散している方が好ましい。

【００５３】具体的には、凹凸の大きさ（ピッチ）は２～２００$\mu$ｍ程度が好ましい。凹凸の深さ（十点平均粗さ）$R_z$ は０．１～１０$\mu$ｍ程度が好ましい。矩形状凹凸の場合は、正規反射面の面積は変化がないため出射側ファイバに入射する界面反射ノイズ光成分は低減されない、したがって、凹凸形態は△（鋸歯状）が好ましい。

【００５４】凹凸面上に形成された透明電極と液晶固化物複合体層との間で生じる界面反射強度をさらに低減するためには、透明電極層の上に$SiO_2$ や$MgF_2$ 等の低屈折率層を反射防止膜として形成することが好ましい。

【００５５】また、反射面と兼用してアルミニウム膜を形成した非透明な裏電極３０Ｃをガラス製の基板３２上に形成した。この構成により、光変調の機能を果たす液晶固化物複合体層３０Ｂと裏電極３０Ｃからなる光反射手段とが密着せしめることができた。裏電極３０Ｃをも透明とし、相対的に屈折率の異なる誘電体膜を光波長程度の膜厚で積層した誘電体多層膜ミラーを重ねて設けて光反射手段とすることもできる。

【００５６】この場合、アルミニウム反射膜に比べ硬いため液晶固化物複合体層のギャップ制御用のスペーサを用いても傷がつき難く耐久性がまさる。また、誘電体多層膜の膜構成を変えることにより反射率及び反射波長帯域を任意に設計できるとともに、ほぼ１００％の高反射率も得られる。

【００５７】ハロゲンランプから発せられる可視光線を反射鏡１４を介して液晶光学素子３０に入射せしめた。そして、液晶光学素子の電極間に１００Ｈｚの矩形波を搬送波とする交流電圧を印加し、実効電圧値を外部回路により変調し液晶光学素子の透過散乱状態を変化させる

ことによって調光機能を有する液晶光学装置が得られた。光ファイバや平凸レンズや透過散乱型の液晶光学素子などをこのように組み合わせて用いた本発明の液晶光学装置の光学特性を測定した。その結果を表１にまとめた。

【００５８】表１において、相対的光透過率は比較例を１００％としている。測定は恒温度槽内で行われ、温度は液晶光学素子自体の温度ではなく液晶光学装置の周囲温度を示す。測定した消光比は０℃から４０℃の温度範囲における液晶光学素子の印加電圧値、０Ｖと３０Ｖに対する出射側の光ファイバ５０の光量値比率の範囲を示す。比較例としては、液晶光学素子の光入射側のＩＴＯ電極面を平坦面化し、平凸レンズの凸面に黒塗りの光吸収体を施さない構成のものに関して同様の光学特性評価を行いその結果を記載した。

【００５９】

【表１】

| | 構　成　内　容 | 相対的光透過率 | 消光比 | 応答速度（ｍｓｅｃ） |
|---|---|---|---|---|
| 実施例１ | 界面に凹凸あり、光吸収体あり | ９８％ | ３００～３５０ | ５ |
| 比較例１ | 界面に凹凸なし、光吸収体なし | １００％ | ３～　１５ | ３～２００ |

【００６０】この結果から、本発明の構成により光損失がほとんどないまま、消光比の飛躍的向上と動作の再現性が改善されている。したがって、本発明の液晶光学装置を調光器などとして用いることにより、印加電圧値に対応した出射光量の調整が光量損失がほとんどなく、任意にかつ高速に行うことができる。

【００６１】また、本発明の液晶光学装置は、出射側の光ファイバの光出射端を被照明物に向けて設置し、光電子増倍管やＳｉフォトダイオード等の光検出器の電気信号をロックイン増幅器によりＳ／Ｎ比の高い光計測をする場合に必要なファイバ式光チョッパーとして利用できる。従来の回転窓式チョッパーもしくは振動型チョッパーに比べて、小型で高速な光チョッピングが可能となる。

【００６２】また、ＣＣＤカメラ等の画像計測装置の画像蓄積と取り込みタイミングと同期させて液晶光学素子を高速シャッタリングすることによりＳ／Ｎ比の高い画像計測が可能となり、画像計測後の画像の二値化処理像を得ることや形状認識等の応用において高精度で高速処理が可能となる。

【００６３】また、本実施例の液晶光学装置を照明装置として用いる場合、バンドルファイバから出射されて円錐状に発散する光は、一般に光軸中心部に暗い部分が生じやすい。これは、光源の発光がランプ管壁やフィラメントによって生じる陰の影響で、開口絞りに入射する光のうち光軸に対して１０°以下程度の角度領域の光が不足するためである。このような不均一性を改善するために、開口絞り位置（光源系に設けられる楕円鏡の第二焦点のほぼ位置にあたる）に錐体状プリズムまたは錐体状反射体を設置し、光軸に対して１０°以下程度の角度領域に光を供給することが有効である。これによって光束の均一化が達成できる。

【００６４】ここで用いられる錐体状プリズムまたは錐体状反射体の形状は、必要とする照射面の照度均一性に対して、光源の配光分布や楕円鏡形状や平凸レンズの焦点距離及びその有効径等に関係して定まる。具体的には、錐体状プリズムを用いる場合はその光出射側の頂角$\theta$が９０°～１７５°である凸錐体状プリズムまたは頂角$\phi$が１８５°～２７０°の凹錐体状プリズムであり開口絞り（正式なアパーチャストップまたは取り付け用のホルダーでもほぼ同等の機能を果たしうる）とともに用いるのがよい。

【００６５】開口絞りによって不要な光が除去され、錐体状プリズムによって光束の均一化、及び一つの光束にまとめられる。光束の太さは、用いられる出射用の光ファイバの口径に応じたサイズにすることが好ましいので、適切な寸法の開口絞りなどを設けるのがよい。

【００６６】光通信分野等において、ファイバ出射光の総光量値のみを必要とし、その配光角度分布に関して制約がない場合、あるいは、光源径から出射される光の配向分布が均等で液晶光学素子への入射光が均一な場合、特に均一化のための素子を設置する必要がなく、開口絞りまたは平板反射鏡でよい。

【００６７】逆に、ファイバ出射光の配向角度分布が不均一で、それに応じて照射部が不均一光量分布となり照明装置として問題となる場合には、錐体状プリズムか錐体状反射体を用いることにより、均一分布に改善される。特に、実施例に示した楕円鏡を集光鏡として用いた光源系においては、中心部に影が生じやすいため、錐体状プリズムか錐体状反射体が有効である。錐体状プリズムは開口絞りと組み合わせて用いるとさらに良好な結果が得られる。

【００６８】また、錐体状反射体を用いる場合は反射面の頂角βが１５０°～１７７°の凸反射体または頂角γが１８３°～２１０°の凹反射体であることが好ましい。この錐体状反射体は、それ自身の有効な反射面積が開口絞りと同様な絞り機能を果たすので簡便である。

【００６９】本実施例においては、第二焦点位置の近傍に錐体状プリズムを用いていないが、この錐体状プリズムをさらに併用すると、光ファイバ照射面の光軸中心における照度は照射面内最大照度の約３０％であったものが、頂角θが１２０°の凸錐体状プリズムを設けることにより、照射面の光軸中心における照度が最大照度となり、動径方向になだらか減少する照度分布が得られ、高速調光機能付き照明装置として良好な照度均一性が得られた。

【００７０】また、集光手段として平凸レンズを用いた場合、レンズの凸面を空気に面し平坦面を液晶光学素子のガラス基板面に屈折率マッチングのとれた接着材で接着することが好ましい。このとき、レンズの凸面と空気との界面において必ず出射側光ファイバに入射する不要な正規反射を生じせしめる曲率部分が存在する。この曲率面部分のみに光吸収体を設けるか、あるいは正規反射低減用の微細な凹凸を形成すればこの界面反射が低減される。

【００７１】ここで光吸収体が形成される面積は微小であるため、液晶光学装置の全体としての光の伝達率にはほとんど影響しない。また、反射面はアルミニウムなどの金属反射鏡でもよいし、光学干渉多層膜反射鏡でもよい。前者の場合、反射面が電極も兼ねるため製造が容易であり、かつ構造が複雑化しないで液晶光学素子が構成できる。後者の場合、光学干渉多層膜の構成によって熱線を透過し可視光のみを反射するような分光特性を有するコールドミラーを形成することも可能であるし、光通信で用いられる特定の半導体レーザ波長に対して反射率１００％のミラーも形成できる自由度がある。

【００７２】本実施例のような光源光学系や集光手段や液晶光学素子、及び出力用の光ファイバの配置構成とすることにより、光ファイバを構成するバンドルファイバへの伝達損失が少なくなり、光利用効率のより高い光学装置が得られた。特に、大光量の、光源を用いることが可能となり低損失であり、かつ精密な光制御が可能となった。

【００７３】本実施例では、光ファイバとしてバンドルファイバを用いたが口径の大きな単一ファイバでもよい。ガラスで直径５ｍｍ程度のコア部を形成すると可とう性がないので、プラスチックや透光性ゴムをコアとして、クラッドを空気とする構造でもよい。空気との界面の汚れを防止するために低屈折率のフッ素樹脂を表面に塗ることが好ましい。

【００７４】バンドルファイバの場合、実際に光が伝送するコア部分の占有面積が５０～８０％と低いため光導入効率が悪いが、このような単線大口径コアファイバの場合、光導入効率は９０％以上と高い。

【００７５】（実施例２）図２に実施例２を示す。本実施例での液晶光学装置は、実施例１とほぼ同様の構成を有する。ここでの特徴は、反射型動作モードを有し光を変調する機能を備える液晶光学素子の一部の界面が光軸に対して斜めになっていることである。具体的には、液晶固化物複合体層が入射光と反射光の対称軸に対して垂直であり平坦な光反射手段９０に対して、所定の傾斜角度αだけ傾斜が設けられている。

【００７６】液晶表光学素子のＩＴＯなどからなる透明な２つの表電極３０Ａ、裏電極３０Ｃの面は平坦である。そして、その液晶固化物複合体層３０Ｂの界面から発生する不要な反射光が出射側の光ファイバ５０に入射して消光比の劣化を招かないように、液晶固化物複合体層３０Ｂが光路に対して傾斜するように配置されている。

【００７７】この傾斜角度αはその界面での正規反射が最終的に出射側の光ファイバ５０に到達するのを低減する値であればよい。具体的には、光反射手段における反射面上の点から光ファイバの有効半径（バンドルファイバの場合は、バンドルファイバ全体の有効半径）を見込んだときの見込み角に対して、液晶固化物複合体の傾斜角αを大きな値にしておけばよい。

【００７８】光通信用単線ファイバの場合、コア径が２００μｍ以下と細いため傾斜角度αは０．１°～１０°の範囲が好ましい。一方、光エネルギー伝送用ファイバの場合には、バンドルファイバとして用いるので光伝送部のファイバ径は２～２０ｍｍ程度と太いため傾斜角度αは、１°～２０°程度が好ましい。

【００７９】さらに、大きな傾斜角度とした場合も、界面反射光は除去されるが、液晶固化物複合体層に斜めから入射する光が大半となり、透明時のインデックス・ミスマッチングに伴うヘイズが生じやすく実効的な透過率が低下する。また、傾斜角度αが大きくなると液晶光学素子が厚くなり、装置全体の大きさ及び重量が増加するため、傾斜角度αは上記の範囲にとどめておくことが好ましい。

【００８０】本実施例では、バンドルファイバ５０の有効半径は２．５ｍｍであり反射面９０までの距離が約５０ｍｍであるため、見込み角は約３°となる。したがって、この場合液晶固化物複合体の傾斜角αを５°にしておけば充分である。

【００８１】光は液晶光学素子の背面に設けられた光反射手段９０によって反射される。これはアルミニウム膜やその他の金属膜でよい。あるいは、可視光を反射し赤外光を透過する光学干渉多層膜を利用したコールドミラーでもよい。

【００８２】温度調整器６０は光反射手段９０の裏側の平坦面に設けることができる。または、液晶固化物複合

体層３０Ｂと光反射手段９０とのなす傾斜角度αに対応した小さな頂角を有するプリズム８０の側面に反射面として形成したあと、液晶光学素子３０と温度調整器６０に光学接着剤で接着してもよい。透過率を低減させないためには、後者のプリズム８０を用いた接着方式が好ましい。

【００８３】本実施例では、温度調整をより正確に行い、広い環境温度に対しても光学特性の再現性を確保するため、光反射手段９０としてコールドミラーを形成し、温度調整器６０として電子制御のペルチェ素子と温度センサが埋め込まれた放熱板を用いた。

【００８４】実施例２の構成で光学特性を評価したところ、－２０℃から８０℃の広い環境温度において、常時消光比３５０という特性を示し、同時に印加電圧対光出力特性も温度変化に対して安定した結果が得られた。また、アルミニウム反射鏡に比べてコールドミラーの方が１０％程度反射率が高いため、相対的光透過率は比較例１に比べ高い値であった。

【００８５】（参考例１）図３に参考例１を示す。この例においては、光の入出力の双方に光ファイバを用い、入射側及び出射側の各光ファイバの端は光路中の集光手段の曲率中心近傍に配置されている。この配置は上述した従来例（図７に示す二つの光ファイバを有する液晶光学装置）と基本配置はほぼ同様の構成となる。平凸レンズ４０は液晶光学素子３０の表側に接着層を介して密着せしめられている。

【００８６】この参考例１においては、液晶光学素子３０の一方の電極３０Ａの界面に凹凸を設けている。この凹凸で、液晶光学素子の不要な界面反射を除去できる。液晶固化物複合体３０Ｂと光反射手段である非透明な裏電極３０Ｃとはほぼ平行に設けられている。

【００８７】さらに、参考例１の液晶光学装置において、実施例１及び２と同様に液晶光学素子を反射面側から強制温度制御しうる構成となっている。強制温度制御法としては、放熱板を装着して空冷ファンで冷却する。あるいはペルチェ素子、電熱ヒータと温度センサを装着して、一定の温度に維持されるよう加熱と冷却を行って温度制御することもできる。

【００８８】（参考例２）図４に参考例２を示す。この液晶光学装置は、参考例１と異なり、電極面は平坦な面とされている。この場合、ガラス基板でなくＩＴＯ付きＰＥＴフィルムを基板に用い、透過型素子を形成してから反射面に接着することも可能である。

【００８９】これらの参考例において、平凸レンズ４０としては球面レンズ以外に非球面レンズでもよく、一方の入射用の光ファイバ５１から出射された光が集光手段である平凸レンズ４０により集束されて共役的な位置にある出射用の光ファイバ５２の光入射端の位置にほぼ集光されればよい。液晶光学素子３０と外界（空気または筐体内部の封入ガスなど）との界面反射が出射側の光ファイバ５２に入射して消光比の劣化を招かないように、液晶表示素子の中心に直径約１ｍｍのスポット状の黒色塗料を塗って光吸収体７０を設け、その部分の反射をなくした。

【００９０】また、透過率を向上させるために平凸レンズ４０の凸表面４０ａには反射防止膜をコートしてある。これらの参考例でも、放熱板を接着して温度調整を実施例１と同様の方法で行った。

【００９１】参考例１及び参考例２の構成で光学特性を評価したところ、実施例１とほぼ同様に、良好な消光比の評価結果が得られた。以上の説明において、液晶光学素子と平凸レンズとを分離して作製したあとで接着し一体化しているが、平凸レンズの平坦面にＩＴＯなどの電極を直接形成しそれ自体を液晶表示素子の片方の対向電極基板としてもよい。

【００９２】（参考例３）図４の参考例２とほぼ同様な構成であるが、入射側及び出射側の光ファイバをエネルギー伝送用のバンドルファイバの代わりに光通信情報伝送用の単線光ファイバを用い、集光手段である平凸レンズの焦点距離が２０ｍｍ、有効径が１０ｍｍのプラスチック非球面平凸レンズを用いた。液晶光学素子の有効面は平凸レンズの有効面よりも大きい形状とした。

【００９３】単線光ファイバは光伝送部であるコアが直径２００μｍの多成分ガラスファイバを用いた。また、平凸レンズの凸面の中央部に約０．５ｍｍの黒塗りを光吸収体として形成した。他の構成は参考例２と同じとした。用いた光源は発振波長８５０ｎｍの半導体レーザで、反射面には８５０ｎｍの反射率が１００％である誘電体多層膜ミラーが形成された上に透明電極としてＩＴＯ膜が形成されている。

【００９４】この構成で光学特性を評価した結果、－２０℃～８０℃の広い環境温度で常時消光比が５０００、応答速度が３ｍｓｅｃという特性を示し、同時に印加電圧対光出力特性も温度変化に対して安定した結果が得られた。

【００９５】このように、参考例の構成により光損失はほとんどないまま、消光比の飛躍的向上と安定性が達成されている。したがって、参考例の液晶光学装置であっても光通信用の可変光減衰器として用いることにより、印加電圧値に対応した出射光量の調整が光量損失なく、任意にかつ高速に行うことができる。

【００９６】（実施例３）図５に実施例３の全体的な配置のブロック図を示す。液晶光学素子３０はその一部拡大断面図を示している。光源系の基本構成は実施例１と同じであるが、光源として１５０Ｗ、アーク長５ｍｍのメタルハライドランプを用いた。また、開口絞り１４の開口位置に、直径１０ｍｍ、頂角βが１６０°の錐体状プリズムの側面にコールドミラーが成膜された錐体状反射体１３を配置し、頂角の２等分線が光軸３０°傾けて配置した。このような錐体状反射体１３を用いることに

より、液晶光学素子３０への入射光の照度分布が均一化された。

【００９７】本実施例での液晶光学素子３０は、対向する電極が同じ形状になるように複数に分割され、個々の分割された電極対毎に電圧を印加し駆動できるような電極構成としている。また、各電極対毎に平凸レンズが１対１にアレイ状に配列され液晶光学素子の表面側に接着層を介して密着せしめられている。実施例１と同じ構成の光学光源系から液晶光学素子へ入射した光が個々の平凸レンズを通して各電極対に挟持された液晶固化物複合体層３０Ｂに入射する。

【００９８】液晶固化物複合体層３０Ｂの一方の電極側（裏側）に形成された光反射手段（裏電極自身で兼用するか、その裏側に専用の反射面を形成する）で反射され、反射光は再び同じ液晶固化物複合体層３０Ｂ及び各平凸レンズを通って異なる位置に集光され、平凸レンズの数に対応した光源系の開口絞りの共役像が複数生成される。この共役像は各平凸レンズの個数に対応して、各々分離して形成されるため、結果的に分割された電極対の数だけ集光点が生成される。

【００９９】この複数の共役像が形成される集光点に共役像の大きさに対応した有効径を有する複数の光ファイバを光出射側に設置する。したがって、各電極対間に印加される高周波電圧を独立に制御することにより、各電極対間の液晶固化物複合体層３０Ｂの散乱状態が各々独立に変わり、出射側の複数の光ファイバの出射光量を独立に制御できる。

【０１００】本実施例では、正六角形の電極対を７個（中心１個、外周６個）隣接して配置し、独立に電圧印加できるように配線した電極基板を用意し、光入射側の表電極３０Ａは実施例１と同様の凹凸が形成されたフロスト面とし、もう一方の裏電極３０Ｃは反射面を兼ねてアルミニウム電極とした。

【０１０１】そして、実施例１と同じ液晶固化物複合体の材料を注入露光し、固化物を硬化せしめ透過散乱型の液晶光学素子３０を形成した。さらに、各電極対にその形状に対応した正六角形で焦点距離８０ｍｍの平凸レンズのアレイを接着し、レンズの凸面の中心に直径約２ｍｍの黒塗りを光吸収体７０として施した。

【０１０２】液晶光学素子と平凸レンズのアレイが一体化された素子を上からみた平面図を図６に示す。図５に示された液晶光学素子３０の一部拡大断面図は、Ａ－Ａ’の切断面に対応する。なお、温度調整器６０は実施例１と同じ構成とした。

【０１０３】光源系の錐体状反射体１３と液晶光学素子３０との距離を約１２０ｍｍとり、液晶光学素子３０に入射する光の光軸が約１０°傾斜するように配置した。液晶光学素子３０が透明のとき、焦点距離８０ｍｍの平凸レンズのアレイと液晶光学素子の反射面によって、錐体状反射体面の共役像が液晶光学素子と６０ｍｍ離れた位置に７個の直径約５ｍｍの円形として形成された。各々の共役像位置に直径６ｍｍの光ファイバを合計７本設置した。

【０１０４】ここで用いられた光ファイバは、透光性シリコーン樹脂を材料とするエラストマーを棒状に加工した物を直径６．５ｍｍのコアとし、外周に低屈折率のフッ素樹脂をクラッドとして被覆したものを用いた。このような単線光ファイバを用いることにより、ガラス系光ファイバを束ねて用いたバンドルファイバに比べて光伝送ロスが大きくなるため長距離伝送には適さないが、コア面積が大きく取れるため光導入効率が高いため、１０ｍ以下程度の光エネルギー伝送においては全体の伝送効率は高く、また低コスト化が可能となる。

【０１０５】本実施例の液晶光学装置を用いることにより、効率よく単一光源からの出射光を複数に分割して光ファイバにより導光できるとともに、各光ファイバにより導光される光の光量を独立にかつ高速に安定して調光することができた。したがって、本実施例の液晶光学装置を自動車に搭載すれば、単一光源から複数の光ファイバにより分割して導光し、ヘッドランプや、テールランプや、室内灯や、インストルメントパネル用光源として用いることができる。また、舞台照明や店内照明のダイナミックな演出に適した機能を有する。

【０１０６】本実施例の液晶光学装置において、単一光源からの光をダイクロイックミラーを用いて色分離もしくは色合成する機能と組み合わせることにより、各色光の調光または任意の色の調光が可能となる。

【０１０７】また、本発明の構成上、液晶光学素子の片面に温度調整器を設置することができるため、強制的な温度制御により、用いられる光量や波長帯域や周囲環境温度に関係なく常に液晶光学素子の最適特性が発現される温度に保つことができるようになり、安定した調光または光シャッタリングが得られる。

【０１０８】以上、実施例について説明を行ったが、次に各部の大きさなどについて概略説明を行う。光エネルギーを伝送する場合には、光源としてハロゲンランプ、メタルハライドランプ、Ｘｅランプ等が用いられ、いずれも発光長が２～１０ｍｍ程度あるため、集光手段を用いて効率よく集光し、ファイバに導光するためには３～１０ｍｍ程度のファイバ直径が必要となる。

【０１０９】また、光源の大きさは、長さ３～１０ｃｍ（１０Ｗ～５００Ｗクラス）から１０～３０ｃｍ（５００Ｗ～３ｋＷ）程度の幅があり、光源の種別に応じて集光鏡の大きさも合わせることになる。液晶光学素子の大きさは、用いる集光手段（楕円鏡やレンズなど）の大きさ、例えばその焦点距離や有効径とファイバのＮ．Ａ．等に応じて決まるが、上記光源を用いる場合は、およそ対角１～３０ｃｍ程度のものを用いる。本発明においては、液晶パネルの大きさにかかわらず、高い特性を達成できる。

【０１１０】通信や光計測等の目的に用いる場合には、光の入射口径は１ｍｍ以下であり、レーザダイオートやＬＥＤの発散光を集光するためにレンズを用いても、その直径は１ｃｍ以下となる。光通信用単線ファイバの光伝送部コア径は２００μｍ以下程度なので、液晶光学素子の大きさは、およそ１～５ｃｍ程度となる。光は、半導体レーザ光などが用いられるためほぼ単一の波長となる。この場合でも、光量が相対的に小さくとも、精密な制御と安定した動作が保証される。

【０１１１】（参考例４）図８に参考例４を示す。上述した傾斜角度αを備えた実施例をさらに改良したもので、楔状のプリズム体を２個用いて液晶光学素子に傾斜角度を与え、かつ反射面と平凸レンズの平坦面をほぼ平行にした例である。上述した実施例と同等の特性が得られた。

【０１１２】

【発明の効果】本発明の液晶光学装置によれば、電気的に散乱状態と透過状態を制御しうる液晶光学素子と光反射手段と集光手段などにより、光源から出射された光を液晶光学素子の光変調部分に２回通過させるため、１回しか透過しない場合に比べて実効的散乱能が飛躍的に向上した。

【０１１３】また、不要な正規反射光低減手段として、液晶固化物複合体層と透明電極との界面に凹凸を形成するか、あるいは、液晶固化物複合体層と反射面とを平行とせず傾斜を付ける、さらには、空気との素子界面において液晶固化物複合体層を通過しないで直接光ファイバに入射する界面反射面部分に光吸収体を設けることにより、バックグラウンドノイズの主因である不要な界面反射光を低減できた。その結果、印加電圧に応じた可変調光機能における消光比及びそのダイナミックレンジの向上が達成された。

【０１１４】また、本発明の構成上、液晶光学素子の片面に温度調整器を設置できるため、精密な温度制御を行うことができ、用いられる光量や波長帯域や周囲環境温度に関係なく常に液晶光学素子の最適特性が発現される温度に保つことができるようになった。そして、大光量の光を伝播制御するときでも、安定した調光または光シャッタリングが得られた。

【０１１５】また、高速シャッター機能を有する照明用光源としては、ストロボ照明がある。この場合には、すなわち、高速撮影が可能となる。具体的な例としては、シャッター速度が１ｍｓの場合、３６０ｋｍ／ｓの速度で移動する物体に照射すれば、１ｃｍの移動平均画像が記録される。

【０１１６】また、高速移動物体を連続的にシャッタリング照明して撮影すれば、軌跡がステップ状に記録される。

【０１１７】シャッタータイミングを任意に可変でき、高速追従性があるというプログラマブルな特質を利用した例として、例えば、広告照明や展示物照明やフロアー照明が挙げられ、ＢＧＭの音の強弱あるいは音色と同期してシャッタリングまたは調光することにより、よりアクティブな照明が可能となった。

【０１１８】本液晶光学装置を、光同期増幅検出（ロックインアンプ）用の光源制御として用い、一定周期でオン－オフする計測用光源の制御機能を担い、その周期の信号光だけを増幅し、検出することによって微弱な信号光でも、またはノイズ光の多い環境でも、Ｓ／Ｎ比の高い計測が可能となった。

【０１１９】その結果、本発明の液晶光学装置を調光機能付き照明装置、あるいは光シャッタリング機能付き照明装置として光計測に利用できるようになった。

【０１２０】特に、ロックインアンプ用光チョッパー等のように光検出装置と同期を取ってシャッタリングを行うことによりＳ／Ｎ比が改善された。また、光通信分野においても、従来より用いられていた固定減衰率の光減衰器に代わって、印加電圧調整により減衰可変な光減衰器を得ることができるようになった。

【０１２１】また、特に大容量の光源を光変調機能を有する液晶光学素子を近接して設け、強度の強い光を精密にかつ安定して制御することができる。

【０１２２】また、本発明はその効果を失わない範囲で種々の応用に適している。

【図面の簡単な説明】

【図１】実施例１（楕円鏡、開口絞り、光吸収体、凹凸面の表電極、出射側の光ファイバを備えた例）の全体的な配置を模式的に描いたブロック図。

【図２】実施例２（光吸収体と傾斜角度αを備えた例）のブロック図。

【図３】参考例１（光吸収体と凹凸面の表電極を備えた例）のブロック図。

【図４】参考例２（光吸収体と傾斜角度αを備えた例）のブロック図。

【図５】実施例３（楕円鏡、開口絞り、錐体状反射体、平凸レンズアレイ、凹凸面の表電極など備えた例）の全体的な配置構成を示すブロック図。

【図６】実施例３に用いられる液晶光学素子の平面図。

【図７】従来例のブロック図。

【図８】参考例４（プリズム体を２個用いて液晶光学素子に傾斜角度を与え、かつ反射面と平凸レンズの平坦面をほぼ平行にした例）のブロック図。

【符号の説明】

１：液晶光学装置

１１：光源

１２：楕円鏡

１３：錐体状プリズムまたは錐体状反射体

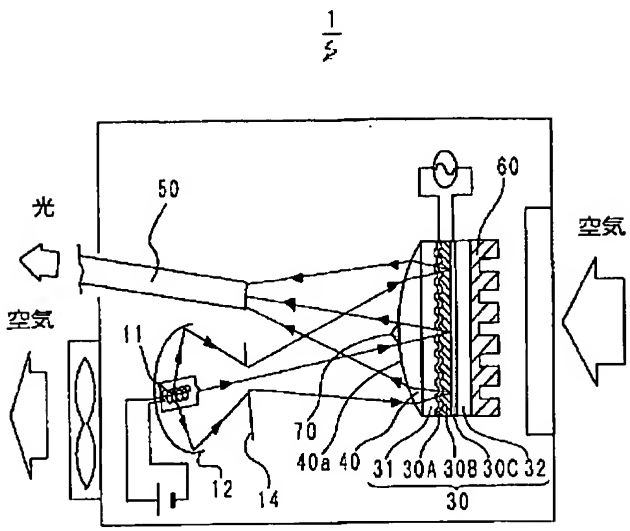
１４：開口絞り

３０：液晶光学素子

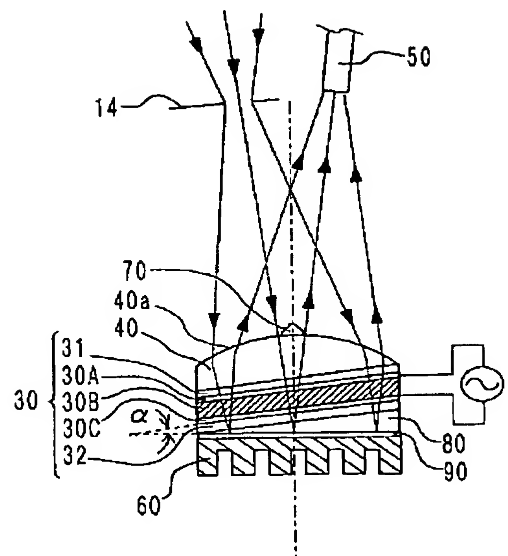
３０Ａ：表電極

３０Ｂ：液晶固化物複合体層
３０Ｃ：裏電極（透明電極または非透明なアルミニウム電極）
４０：平凸レンズ
５０：光ファイバ
６０：温度調整器
７０：光吸収体

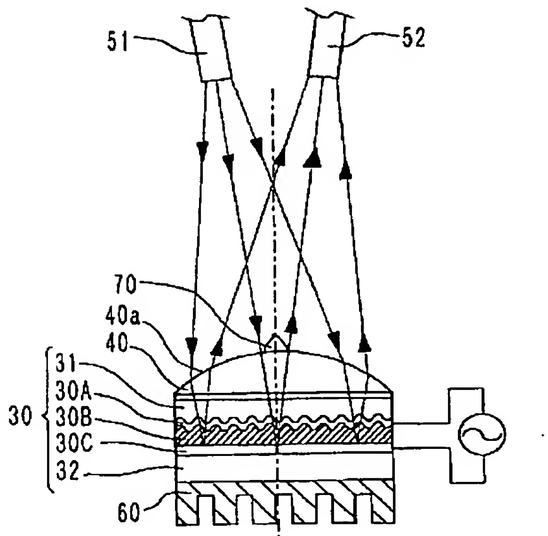
【図１】



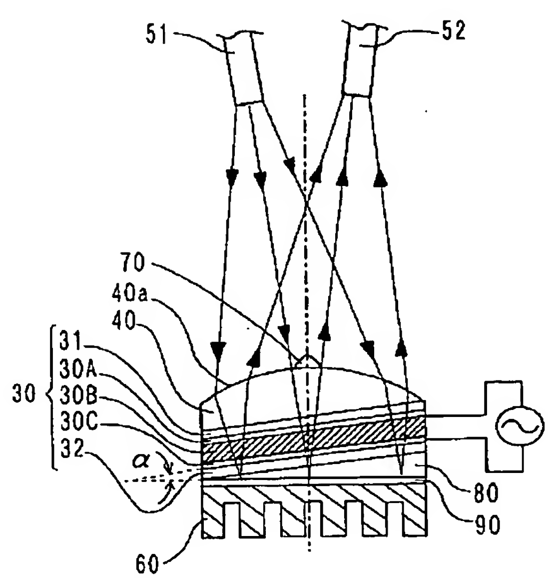

【図２】



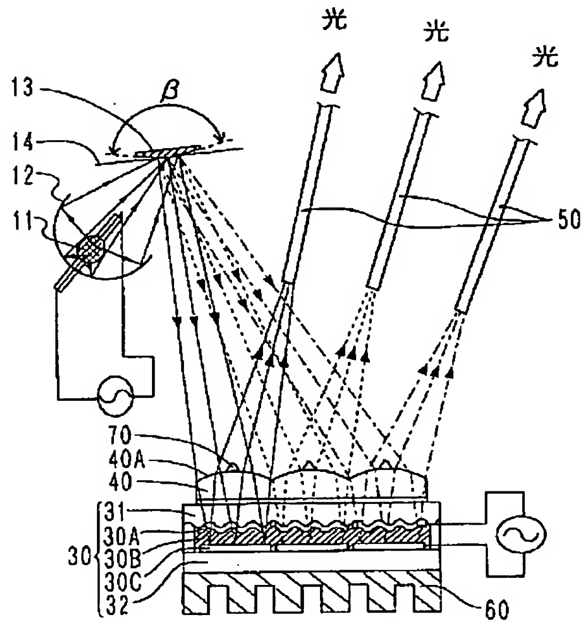

【図３】




【図４】



【図5】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70
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31
30A
30
30B
30C
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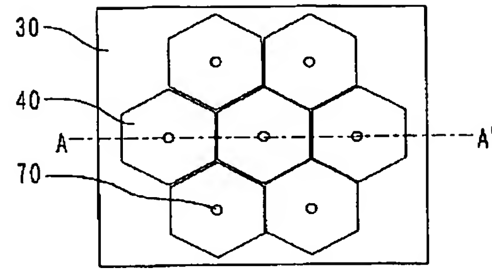
60

【図6】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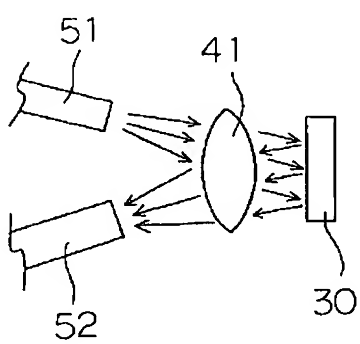
【図7】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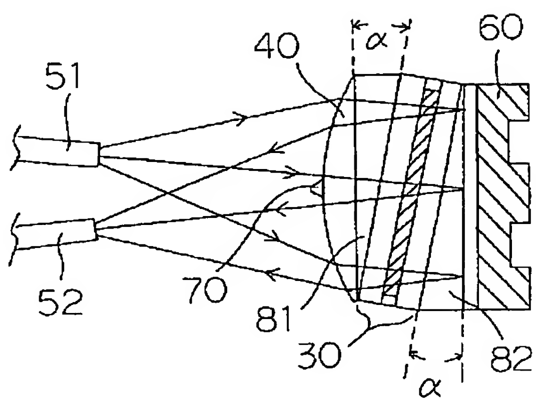
30

【図8】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α